ASTRONOMY

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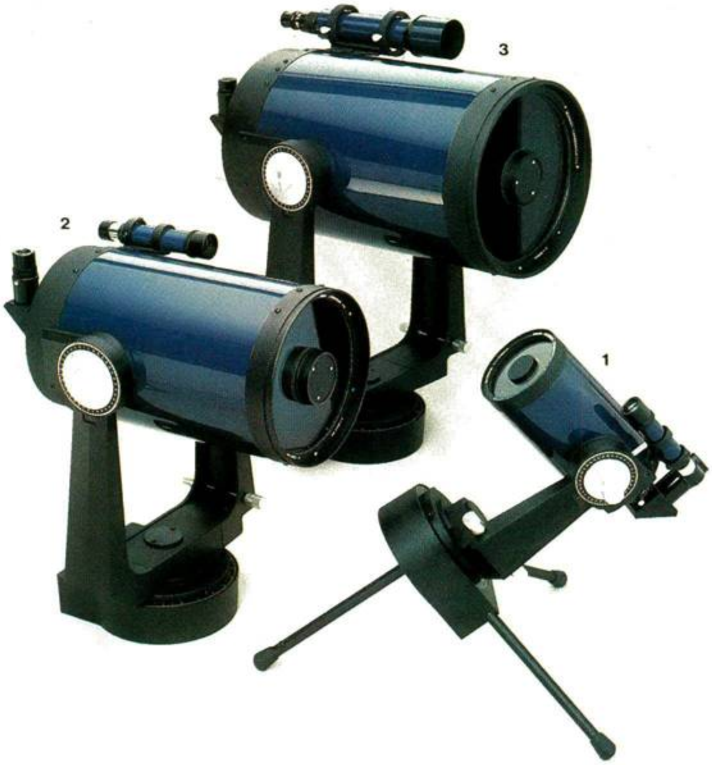
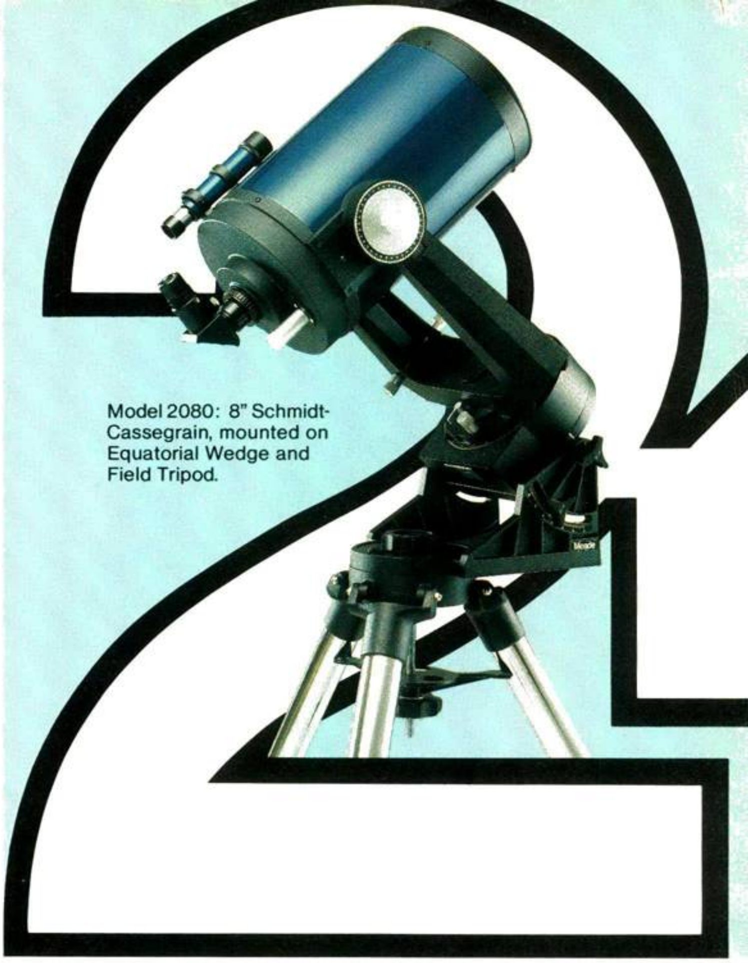
Space Station: 1993
How to Observe Satellites
Find the Summer Constellations

ICD# 08070 71574

Spiral Galaxy M-83

Meade Schmidt-Cassegrain Telescopes: **(1)** 4" Model 2044, with standard-equipment table tripod; **(2)** 8" Model 2080; **(3)** 10" Model 2120.





Model 2080: 8" Schmidt-Cassegrain, mounted on Equatorial Wedge and Field Tripod.

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4 PLUS

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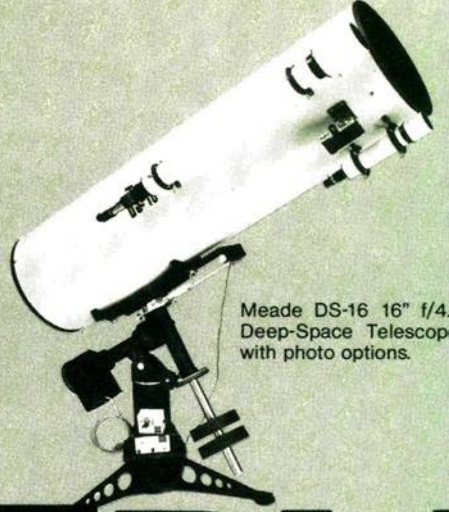
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Cover: The spiral galaxy M-83 in Hydra. Photo courtesy Royal Observatory, Edinburgh. This month, ASTRONOMY's lead feature showcases possible designs for a Space Station. Then we explore a thorny question — will the Galileo probe to Jupiter contaminate the planet? These pages: The Great Square of Pegasus rising at dawn in May over the buttes of Monument Valley, Utah, hints at the forthcoming beauties of the autumn sky. Photo by Dewey Vanderhoff.

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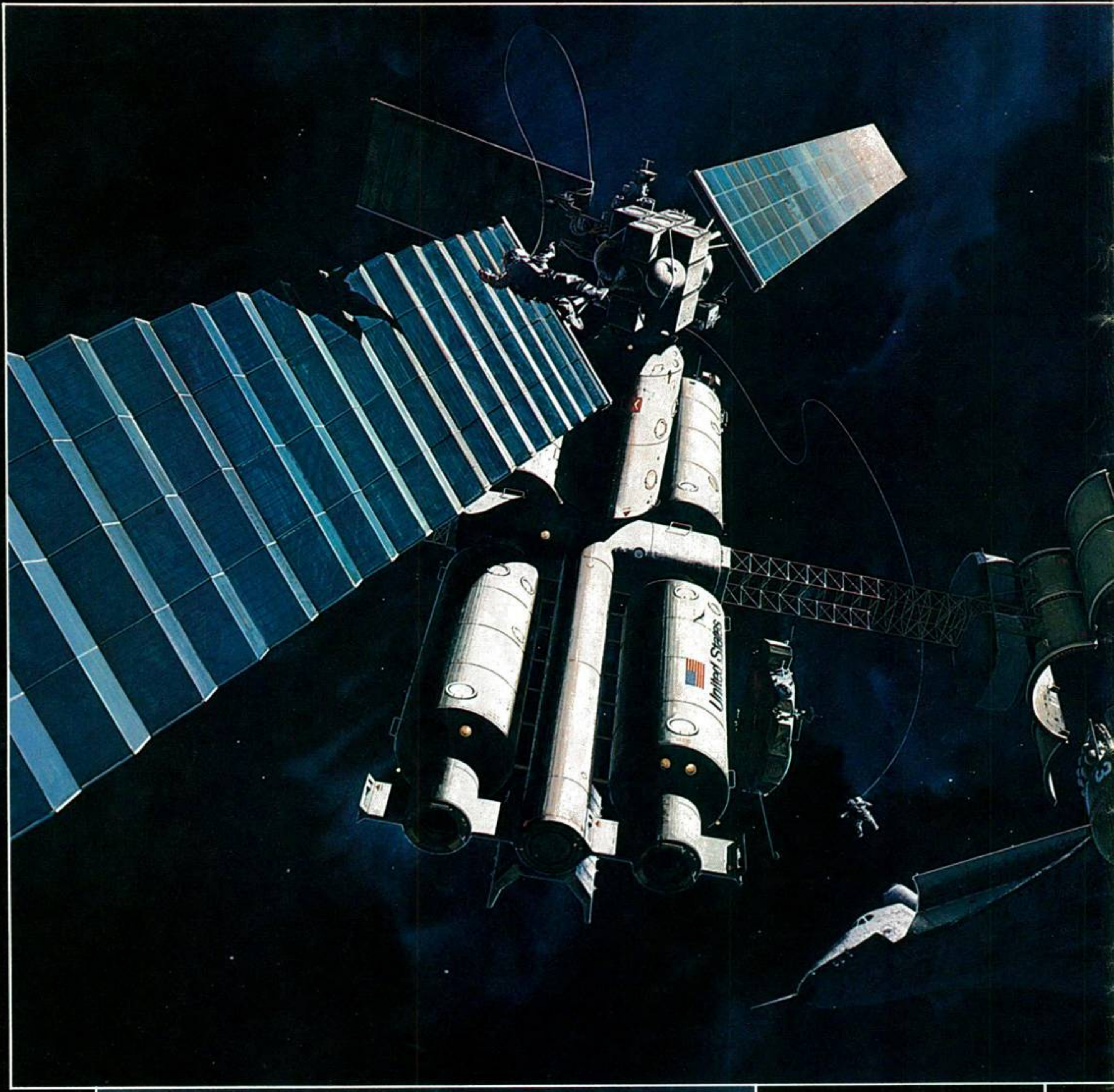
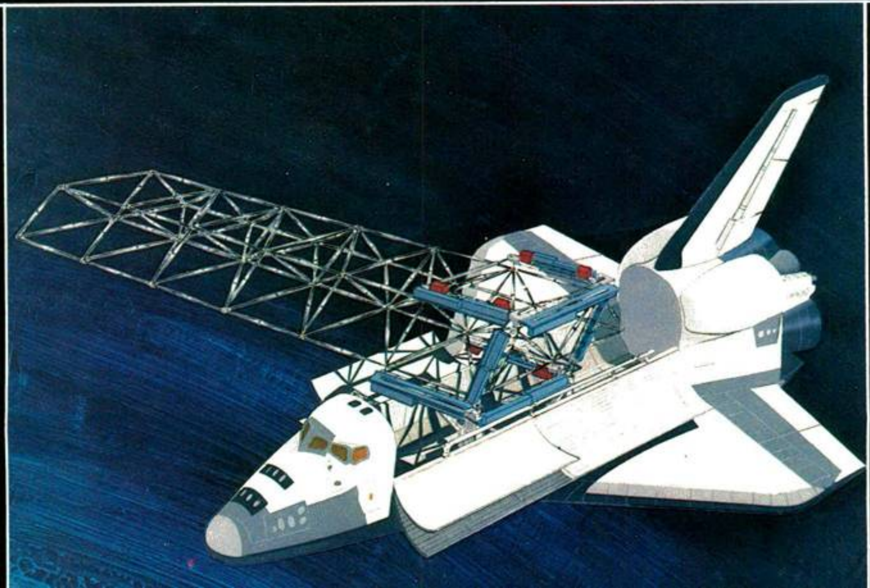


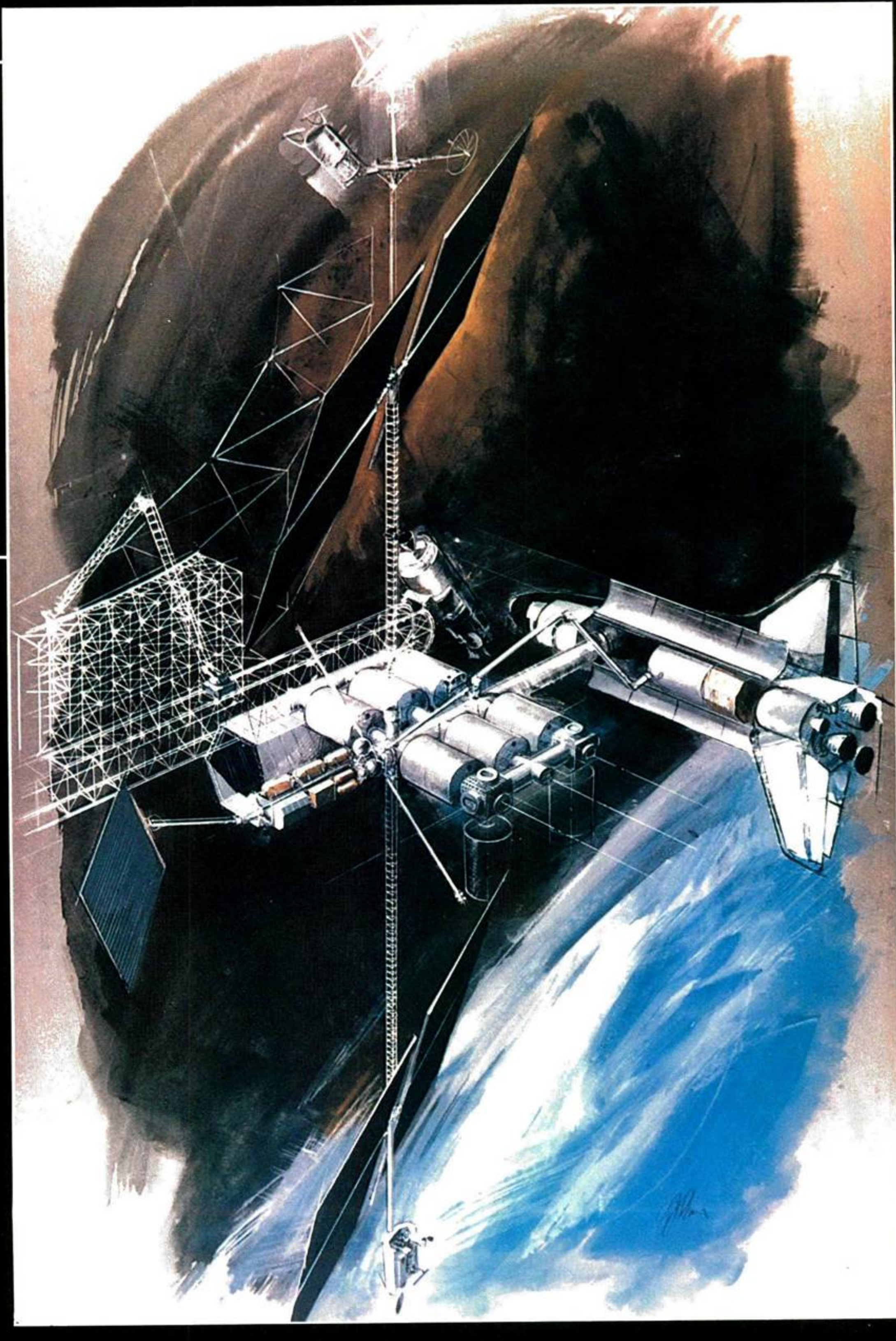


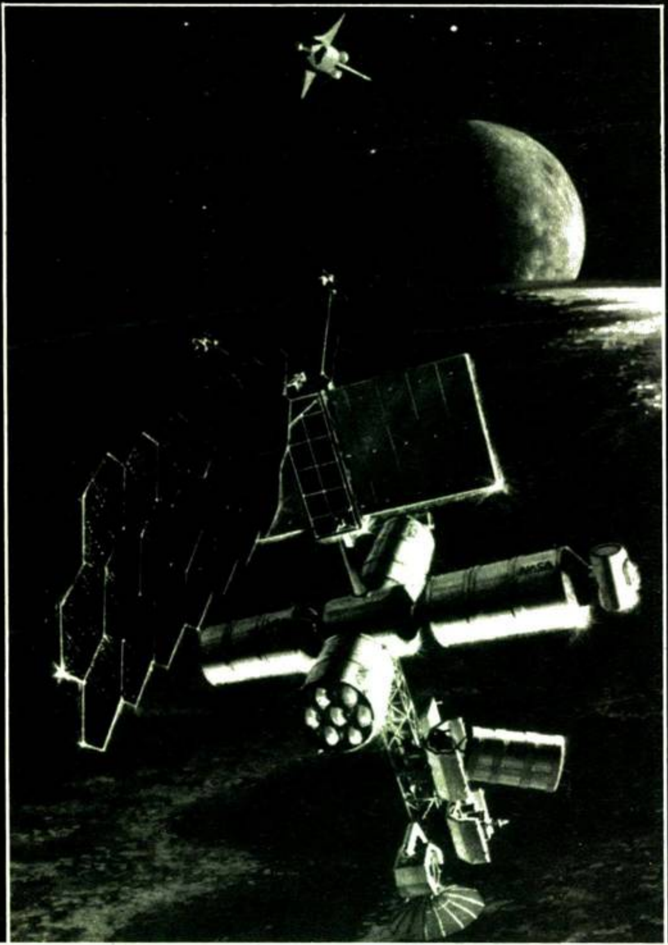
Above: This fully developed station was built in orbit out of parts ferried up from the ground by the Shuttle. First came a central module to form a spine, then later flights added truss-structures, solar arrays, and living and laboratory modules. Left: Another idea involves building space platforms by snapping together graphite epoxy columns and beams. Artwork courtesy Lockheed.

SPACE STATIONS: The High Frontier

TIN MARIETTA
TRW
BOEING
GENERAL DY

This design is intended to house a crew of eight; included are solar electric panels, antennas, living quarters, and Shuttle docking port. The skeleton trusswork of a platform addition is being erected at left center. Artwork courtesy Boeing.

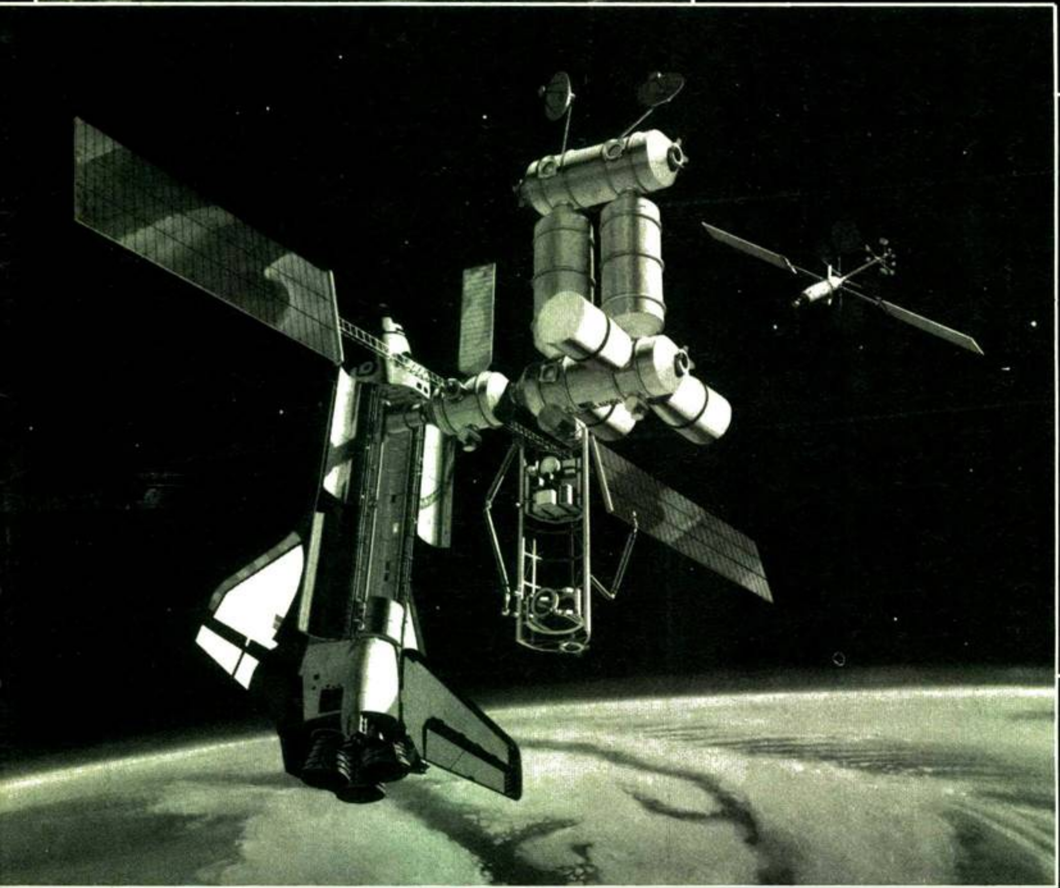




It's June 23, 1993. You and three others are buckled into your seats aboard the Shuttle. You're about to leave behind the stifling heat and towering thunderheads of summertime Florida and swap it for a climate-controlled habitat 250 miles up. For the next six months, the new space station — launched just last year — will be your home. Three hours from now, you'll be pulling yourself hand over hand up the docking tunnel into the control module, where you'll be greeted by the crew members you're replacing. And tonight, having unloaded its supplies and cargo, the Shuttle will cast loose from the station and return to Earth, leaving you and your companions behind.

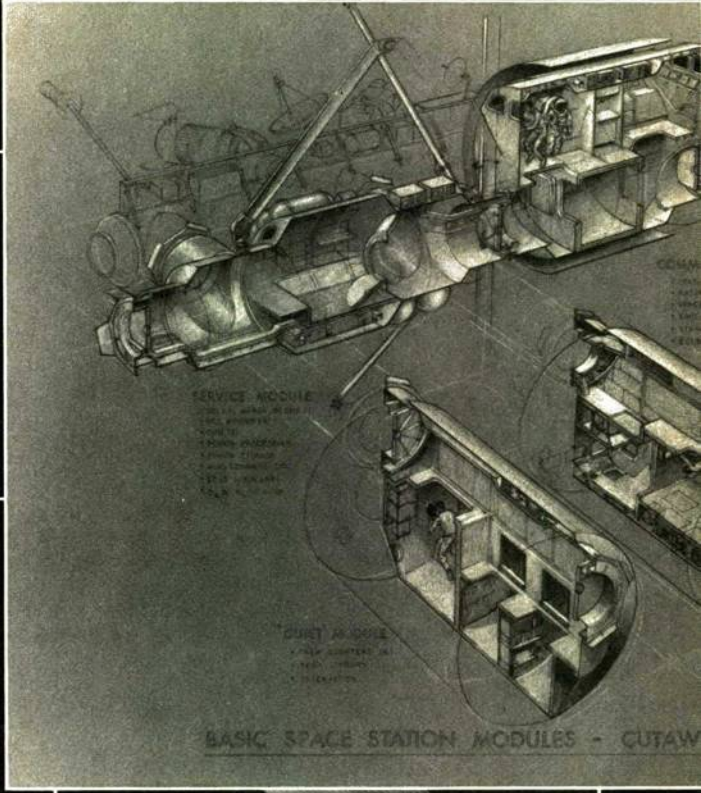
How did you end up here? Two years ago, after getting your M.D., you applied to the space program. Somewhat to your surprise, you endured NASA's rigorous testing and were finally accepted. Now, after many long months of specialized training, you're bound for orbit. At the station, part of your job will be to look after the health of the crew. In addition, you'll also be conducting research into the biological effects of weightlessness — including the still puzzling "space sickness" that debilitates, for the first few days they're in orbit, about half the people who go up. Maybe, you think, I'll be lucky enough to get it, too. . . .

At present, NASA's space station is little more than a collection of ideas. The initial station will undoubtedly be modest, housing four to six crew members. It will probably be a scaled-up version of Skylab, the converted



Left: Here is a modular complex with several docking ports; the station's economy will be based on repairing and assembling satellites in orbit, and on manufacturing pharmaceutical and exotic materials difficult or impossible to fashion on Earth. Artwork courtesy Rockwell International. Above left: TRW's plan, shown here as a Shuttle craft approaches, embodies a four-arm cruciform structure. Artwork courtesy TRW.

Right: Space station astronauts will find fairly roomy quarters, especially when compared with previous generations of manned spacecraft. Apart from the workaday essentials, living modules will also have viewing windows so that off-duty crew members can relax and enjoy the scenery. There will also be opportunities to take naps, write letters, goof off, and in general begin to *live* in space. Artwork courtesy Boeing.


SERVICE MODULE
"QUIET" MODULE
BASIC SPACE STATION MODULES - CUTAW

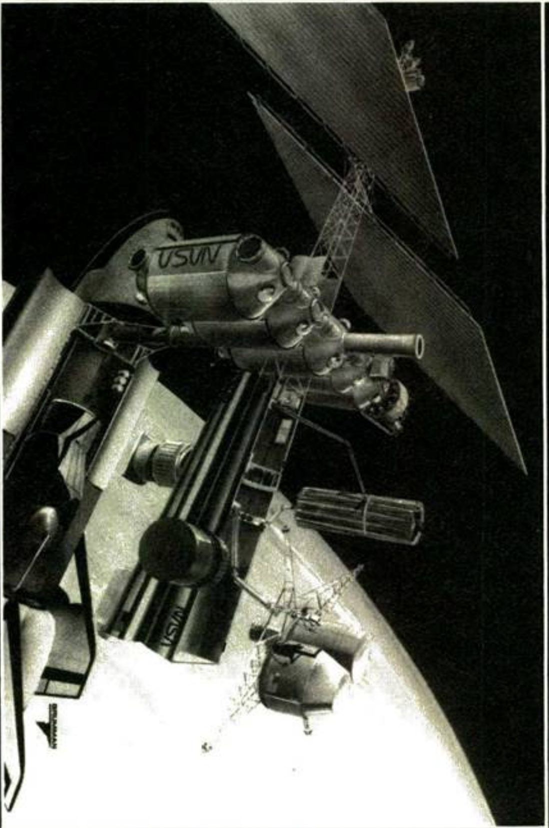
uppermost stage of a Saturn V rocket in which three crews of three astronauts each lived for periods as long as 84 days.

Useful as it was, Skylab's role as a space station was severely limited by the fact that it was a single module with no capacity to grow. Though it contained the basics of any space station — sleeping quarters, eating facilities, and a scientific workshop — Skylab was not designed to be expanded, and the investigations its crew could carry out were necessarily limited.

Skylab's orbit eventually decayed, and it burned up on reentry in 1979. But a similar craft is flying today — the Soviet space station, Salyut. Salyut is reminiscent of Skylab, though much smaller: typically, two cosmonauts inhabit it for six months, receiving visitors and periodic replenishment of station supplies via automated tanker-craft. According to one U.S. congressional study, Salyut crews perform experiments, both biological and metallurgical, and carry out unspecified military missions. Salyut's long missions have demonstrated that humans can withstand up to half a year of weightlessness (and can probably tolerate much more), a finding that is very important if manned planetary flights are to be accomplished.

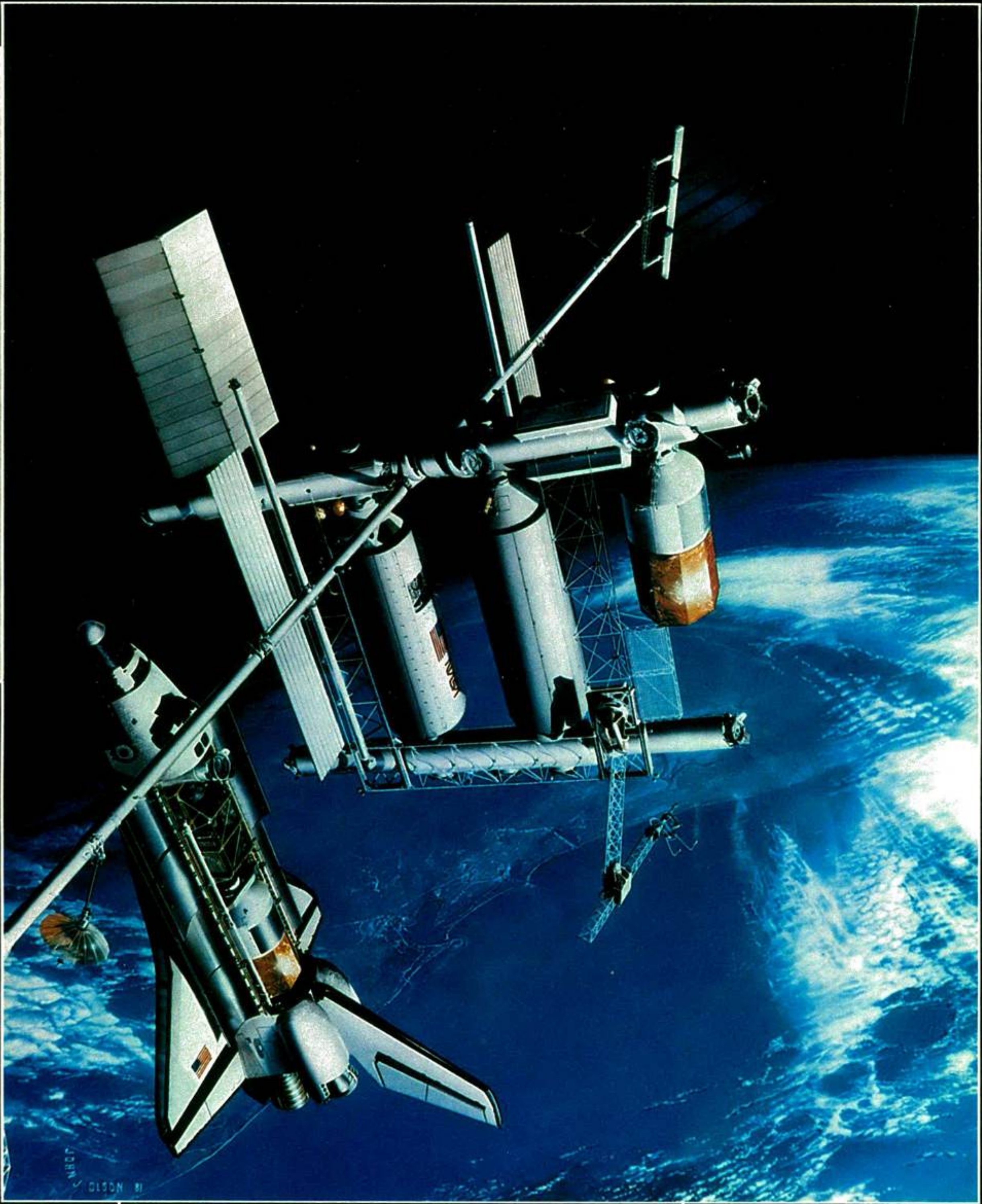
NASA's space station, however, will follow a distinctly different approach. It will be more roomy, and the hallmark of its design will be flexibility. Though NASA must present a clearly defined role to get the funding to build it, the agency also knows that new uses will surface once the station is operational and flexibility is essential to keep the station from quickly becoming obsolete. NASA envisions many uses for it — assembling and repairing satellites, processing metallurgical and pharmaceutical materials under special conditions, conducting biological experiments, and so on. In aiming at commercial uses for space, NASA clearly would like to see the station earning substantial revenue to offset its operating costs, if not actually paying for itself.

To meet its physical needs, the station will require

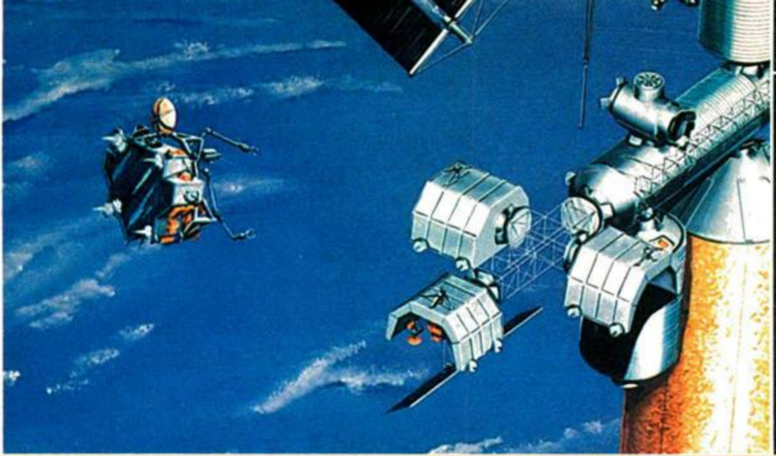


Grumman's concept housed a crew of three to four to begin with and took three Shuttle launches to put into orbit. Later trips added modules for expansion; all modules are attached to a central spine that provides power from the solar cells. Artwork courtesy Grumman.

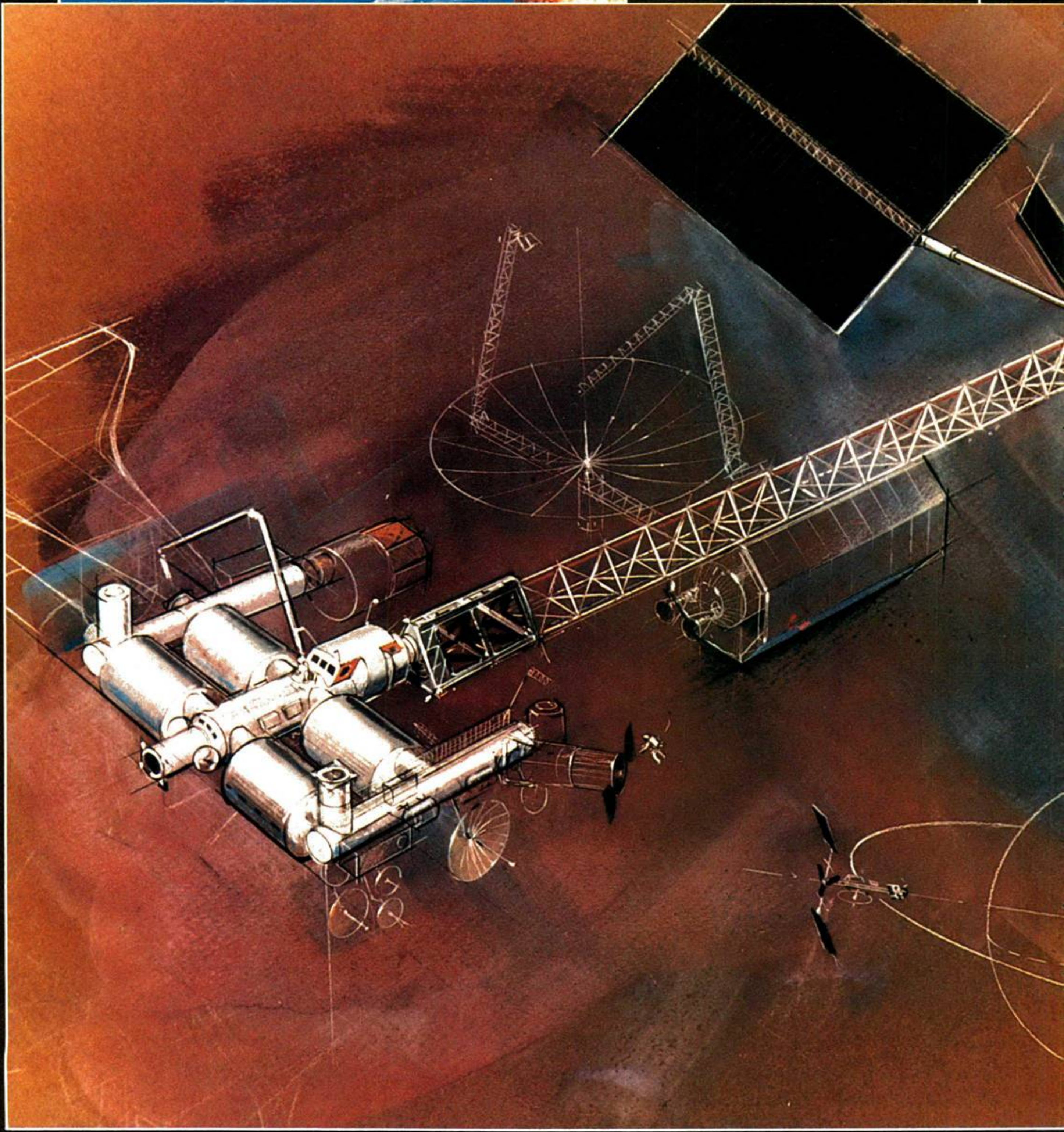
AIR LOCK
ND AND CONTROL
'ACTIVE' MODULE


JOHN OLSON 81

Orbiting 250 miles up, this station concept includes two habitat modules in the center of the structure, which provide living quarters, offices, a hospital, and command post for a crew of eight. Elsewhere are a satellite repair hangar (top left), solar power cells, and various modules for storing propellants, food, water, and other essentials of station life. Artwork courtesy Boeing.



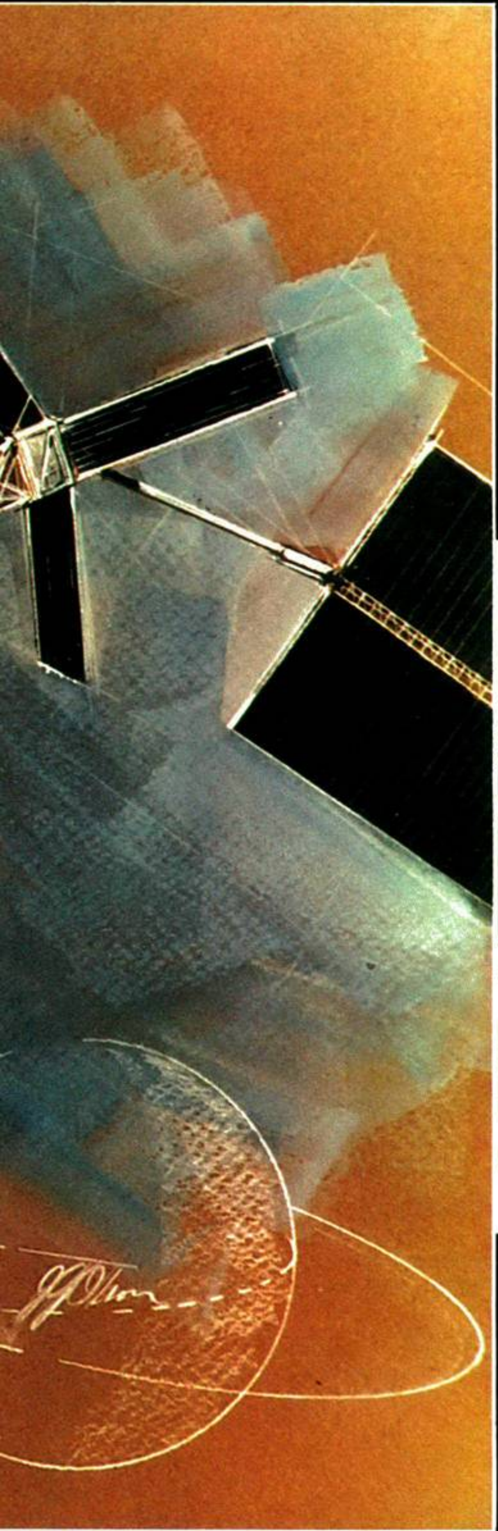
Below: Embodying a "power tower" similar to those used in other designs, this configuration would house eight astronauts and would provide service and laboratory areas. Artwork courtesy Boeing. Left: Essential to many station operations will be a remote-controlled "tug" to maneuver satellites and equipment. Artwork courtesy Martin Marietta.

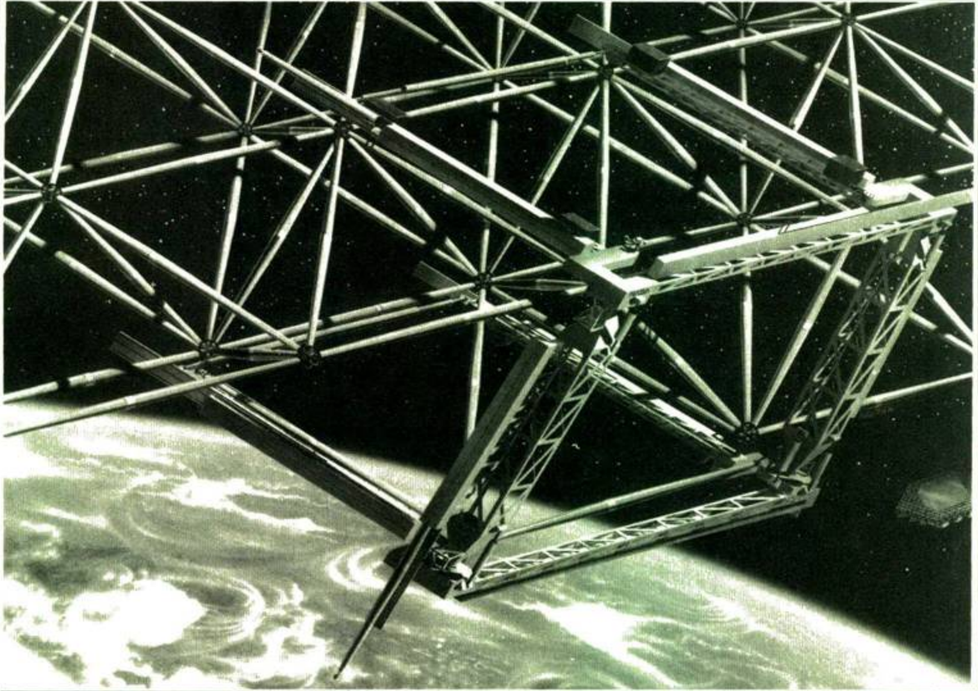


lots of electric power, so banks of solar cells will be a prominent feature. (Nuclear electric generators have been considered for future stations, but solar cells are simpler and available in quantity for less money right now.) There will be a command and control center from which station operations will be run. Repair and assembly of satellites calls for a hangar bay; laboratories will be housed in separate modules, with room to plug in more of them for later expansion.

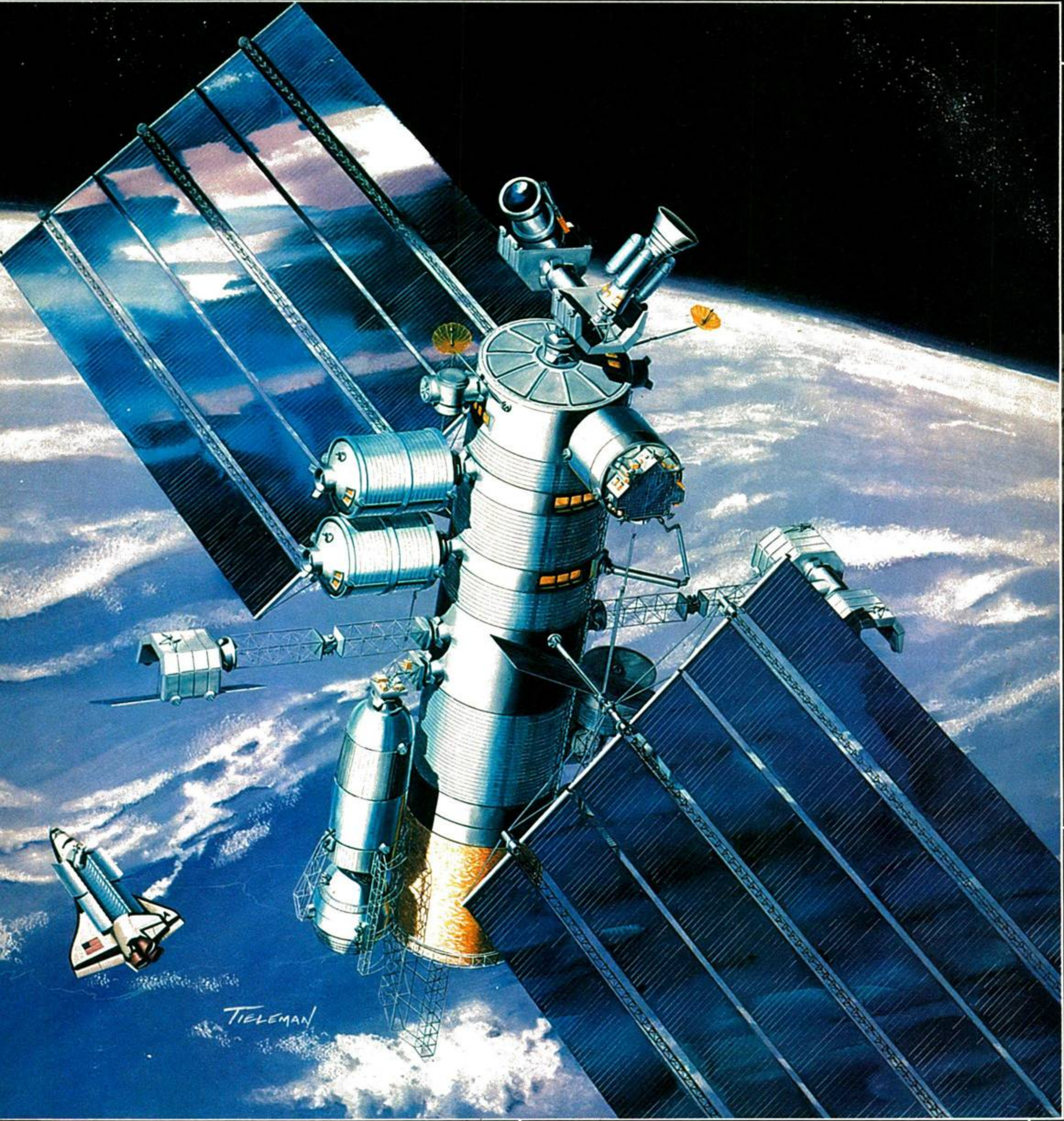
Crew members will need living modules, and since long stays are planned, accommodations will be less spartan than previous craft have provided. Individual sleeping quarters are likely, along with lounge areas (and viewing ports!) to boost morale. Many plans also call for a semi-closed ecology in the station, with hydroponically grown plants providing fresh oxygen and food. Fully closed systems are a possibility for the future.

Where does the project stand now? Assuming Congress approves the station, NASA will combine the preliminary studies done by eight aerospace contractors (Boeing, General Dynamics, Grumman, Lockheed, McDonnell-Douglas, Martin Marietta, Rockwell International, and TRW) into a specific space station proposal by this summer. Then in the fall, NASA will issue the plans and call for bids on various parts of the station, with the first contracts probably being awarded next

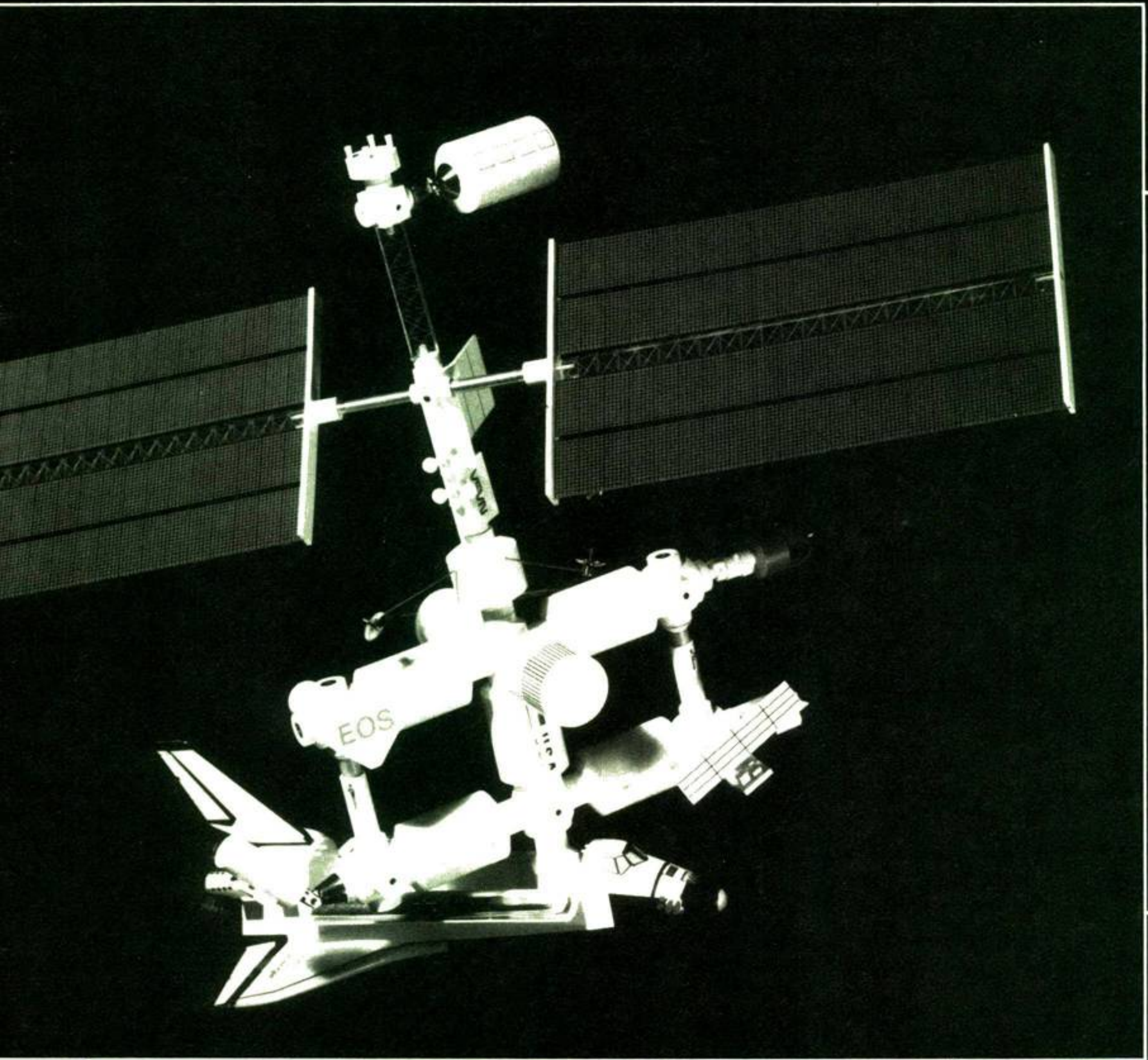




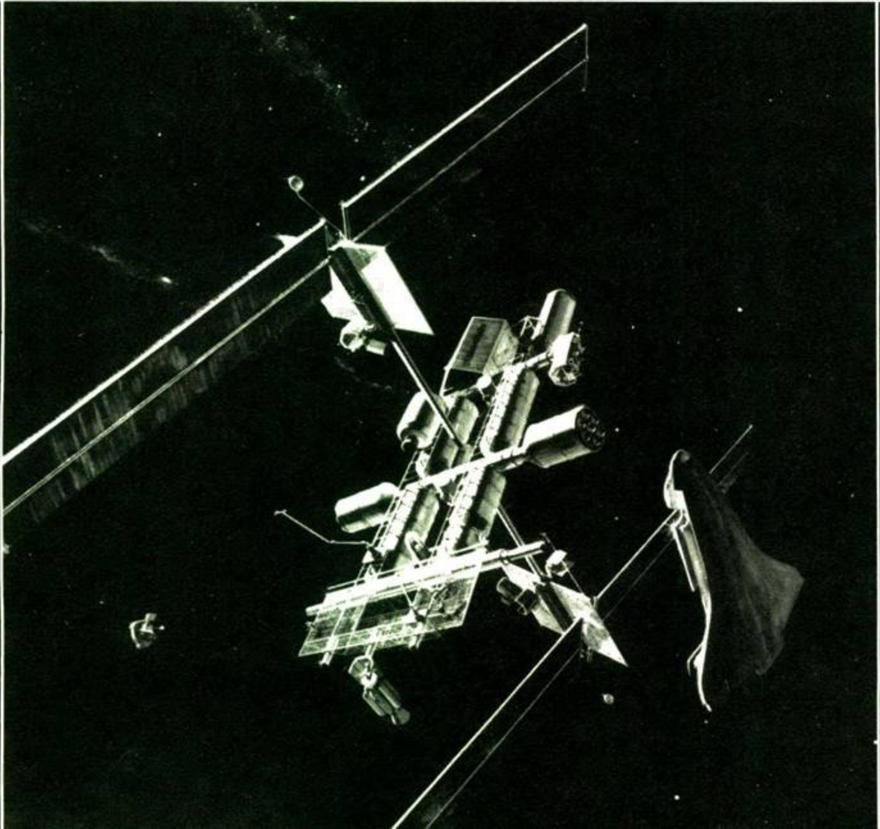
Above: This automatic assembly system could construct a platform the size of three football fields in two days. Each Shuttle would deliver about 5000 graphite epoxy structural members, along with the hardware to join the columns together. Note the tiny spacesuited astronaut at right center. Artwork courtesy Lockheed.

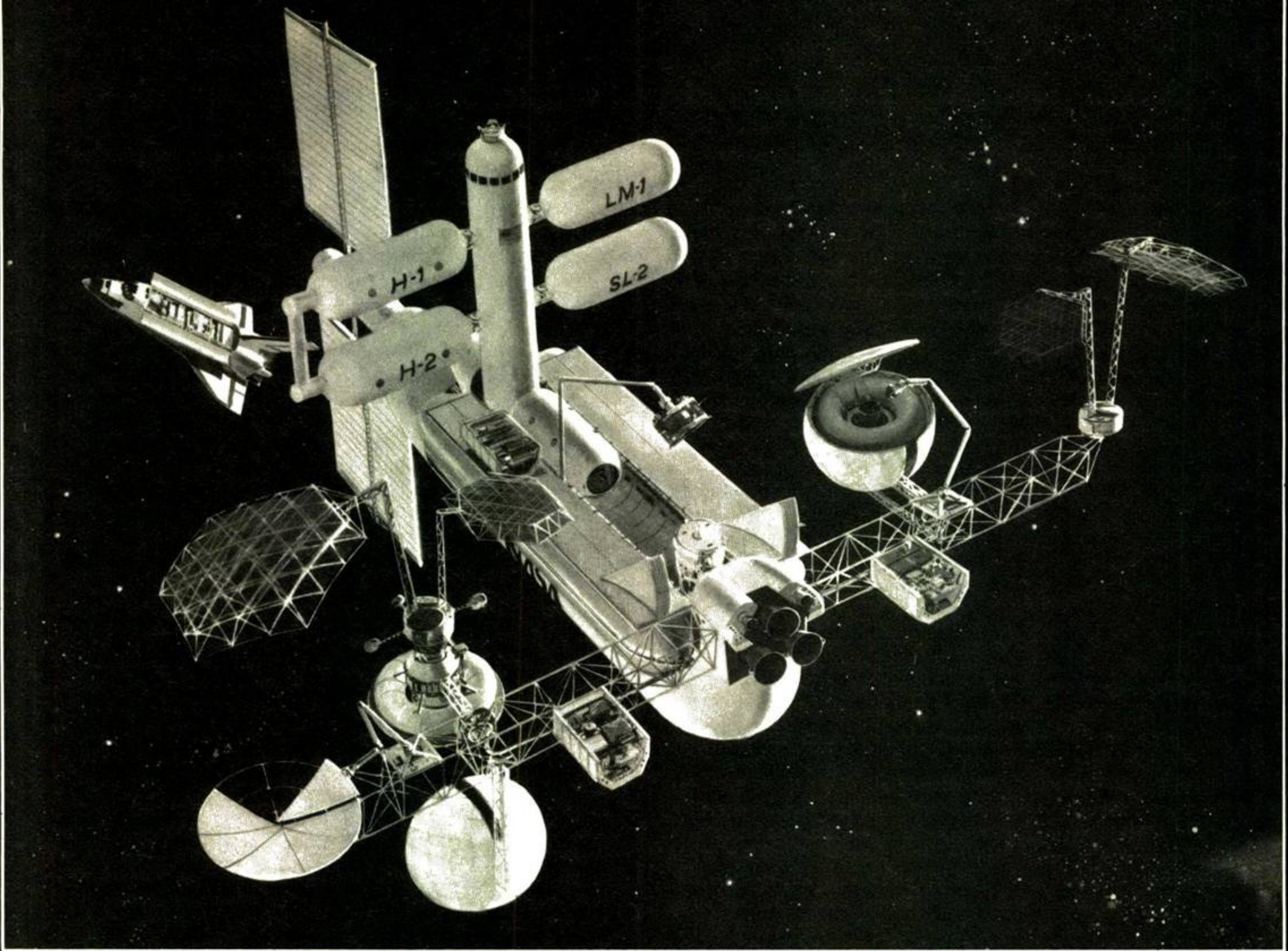


Telescopes, sensors, and other instruments extend from this multi-deck space station. Intended to house 16 crewmembers or more, this station would be launched from the Earth with an external tank of its own; later Shuttle flights would ferry crew, supplies, and additional modules to expand the facilities. Artwork courtesy Martin Marietta.



Left: This photo of a model shows an eight-man station for low Earth orbit. It has five modules: living quarters, two operations bays for repairing satellites and conducting science experiments, a control center, and a storehouse for a three-month supply of oxygen and food. Photo courtesy McDonnell-Douglas. **Below left:** A fully developed station of the mid-1990s. Artwork courtesy TRW.



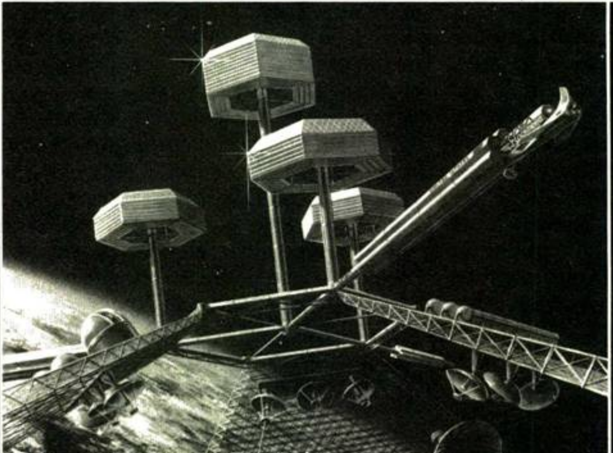


spring.

Learning from its unhappy experience with the Shuttle, this time NASA will spend more money in the design and testing stages. The agency claims this will keep the station to its $8 billion budget, though critics — notably the financially hard-pressed space science community — are highly skeptical of this. In any case, despite a presidential mandate calling for the station to be a bold new step, the station will actually require very little new technology.

Another cost-cutting measure is keeping the timetable loose. The Shuttle was developed under severe pressure to get it flying quickly — potential users, promised launches by a given date, didn't buy expendable launchers in the faith that the Shuttle would be ready. The space station, on the other hand, has no timetable apart from the President's "within a decade" limit — and agency officials speak of it being launched around the early 1990s.

Six incredibly productive, exhausting, and exciting months have passed. Your relief crew is on the way up. You'll be sorry to leave, but there's no denying how good ol' terra firma is going to feel. Blue skies, trees, windblown grass — you'll never again take them for granted. And yet — plans are underway for the Mars Expedition, and surely they'll be needing a doctor. . . .



Top: Attached to this large station concept are three instrumented Spacelab-like pallets (two on the truss beam), several platform antennas, two large solar cells, cannister habitat and laboratory modules, and large hangar work area. Artwork courtesy General Dynamics. Above: A "next-generation" station would have larger living and working modules, and would house perhaps 25 to 50 people. Artwork courtesy Lockheed.

THE STAR TAR IN THE JUPITER JARS

by Linda Joan Strand

"When dealing with the unknown, the outside chance should never be ignored."
— Carl Sagan

In a small, crowded laboratory on the third floor of the Department of Environmental, Population, and Organismic Biology at the University of Colorado, amidst changing collections of test tubes and Petri plates, rises a black wrought-iron stand bearing a watermelon-sized brown glass sphere. A mysterious ring of electrodes girds its belly, and affectionately pinned on its chest is a large button from which "E.T." winks impishly — as if to warn the unsuspecting of both the sense of humor of its guardians and the cosmic implications of the contents of this flask.

The "tholin" inside this flask was made by Bishun Khare and Carl Sagan in their laboratory at Cornell University (those who followed the *Cosmos* television series may recall seeing this selfsame flask in an early episode). Khare and Sagan sent it to a small interdisciplinary group at the University of Colorado where it now resides. Its present guardians are Penelope J. Boston, a graduate student in the Department of EPO Biology, her advisor William Segal, and Carol Stoker, who recently completed her graduate studies with a Ph.D. from the Department of Astro-Geophysics. Boston's area of specialization is the biology of harsh environments, and Stoker's is the vertical cloud structure of Jupiter. The tholin is the product of experiments performed by Khare and Sagan simulating the chemical processes that might take place in the atmosphere of Jupiter — which, interestingly, is similar in many of its components to that postulated to have existed on the primitive Earth at the time of the origin of life.

This tholin began as a mixture of equal parts of methane and ammonia combined with 2.6% water vapor. It was then subjected to electric sparks — the holes in its sides bear witness to the electrodes once inserted. After a week of sparking, its contents were analyzed and found — not surprising by the time Khare and Sagan began the simulation — to contain long carbon-chain molecules including amino acids.

"Not surprising," because this synthesis was in many details the same as its prototype, the now-famous Urey-Miller experiment of 1953. Based on the cosmic abundance of hydrogen, and assuming that the planets condensed out of a protosolar nebula (the leading theory of the formation of the solar system), Alexander Oparin and J.B.S. Haldane had independently hypothesized in the 1920s that life originated in a sort of prebiotic "soup" of organic compounds in a reducing environment — i.e., one rich in hydrogen and chemicals containing mostly hydrogen, especially methane (CH_4) and ammonia (NH_3). Stanley Miller, then a graduate student at the University of Chicago, under the supervision of Harold Urey, took the first step toward lifting the study of the origin of life from a theoretical exercise to an empirical study. In a bold departure from the previous modes of investigating the subject, Miller placed a mixture of methane, ammonia, and water in a flask, sparked it to simulate lightning, and thus created the first amino acids synthesized under supposed primitive Earth conditions. In so doing, he also sparked a rash of criticism and disbelief, as well as a flurry of similar experiments; by now, his result has been confirmed and reconfirmed by dozens of researchers all over the world. Among the first to follow suit was Carl Sagan. Though details of this initial model of the origin of life on Earth have been called into question by recent research, there is no doubt that amino acids and other biologically interesting molecules can be synthesized from methane and ammonia by adding an appropriate amount of nearly any form of energy.

Furthermore, the presence of complex organic molecules on the outer planets — along with other compounds detected among the products of laboratory simulations of the prebiotic soup — is now widely accepted following their spectroscopic identification in the spectra of the outer planets. This suggests that life might emerge spontaneously on the outer planets, as it is believed to have arisen on Earth — if indeed that process has not already begun.

A planet such as Jupiter exhibits all the characteristics required by the Oparin-Miller paradigm for the origin of life. It is made up predominantly of hydrogen and hydrogen-containing compounds, and is believed to have the necessary energy in the form of shock waves, ultraviolet light from the Sun, or heat from the interior of the atmosphere to drive the reactions that make biologically relevant molecules. Some of these molecules have been identified by spectroscopic observation. Therefore, Jupiter and perhaps others of the outer planets may be our best natural laboratories in the solar system to observe the emergence of life — an experiment crucial in testing current theories of the origin of life.

In about three short years, the Galileo spacecraft will be launched toward the giant planet. It will return much-needed information about the atmosphere and magnetosphere of our solar system's largest planet. While the mission as planned will clearly make significant contributions to planetary science, there is a more somber aspect. Unfortunately, no provision has been made to ensure that the probe intended to dive into the jovian atmosphere will not deposit living terrestrial organisms in the jovian atmosphere. In spite of the obvious advantages of sending the orbiter component of the mission, and the potential advantages of including a probe, a question remains:

One thing is clear about the experiment at the University of Colorado: it has raised questions.

Will this probe provide enough critical information to balance the risk of contaminating an alien planet, thereby ruining a practically ideal natural laboratory for future exobiological studies, as well as setting an extremely dangerous precedent for future planetary missions?

"Star Tar"

When the time came, some years ago, to find a suitable name for the sticky, tarlike substance synthesized in the kinds of simulation experiments described above, Sagan and Khare toyed with the phrase "star tar" as both pithy and descriptive. But sobriety won the day, and the word "tholin," from a Greek word meaning "muddy," entered the English language to denote the intractable organic polymer which suggestively resembles the browns, golds, and reds observed in the atmosphere of Jupiter.

"Star tar," while understandably too flip for the scientific press, was not an inappropriate name for this intriguing material, for Khare and Sagan suggested in 1979 that it may be a prominent constituent of the interstellar medium. Though this suggestion is still being hotly debated, it is based on sound (if imaginative) scientific reasoning. Certain spectral lines observed in the light which has passed through interstellar gas and dust are similar in several significant respects to those observed in laboratory analyses of tholin spectra. Khare and Sagan have further suggested that some of the uncertainties surrounding the composition of carbonaceous chondrites might be partially explained if tholins were produced in the primitive solar nebula, eventually becoming constituents of comets, interstellar grains, and carbonaceous chondrites. If tholins are as ubiquitous as Khare and Sagan believe, it would lend credence to the scenario most often called upon to explain the origin of life on Earth: the accumulation of organic compounds in a primitive ocean, leading — by chemical processes — to the emergence of the first simple lifeform, or protocell.

It would be desirable to perform variations on the first tholin biology experiment.

One obvious question is the following: assuming for the moment that life did indeed originate according to this scenario (and we really *don't* know whether it did), what did this protocell *eat*? Most terrestrial organisms live on other organisms or their products, or manufacture food directly from the Sun's energy via photosynthesis. By definition, the first organism could not have depended on other lifeforms for subsistence, and photosynthesis relies on rather complex biochemical pathways generally thought to have evolved later.

In light of this apparent contradiction, the significance of the Boston-Stoker-Khare-Sagan experiment (hereafter referred to as the Tholin Biology Experiment, or TBE) emerges: tholin is something that first cells could eat. The protocells *could* have been "breatharians," living on nutrients produced in the atmosphere.

The ramifications of their findings were described concisely by Boston and Stoker: "If tholins were present on the early Earth and were the building materials and sustenance for early life, then they must have set the pattern for the chemistry of that life. All fundamental enzyme systems, indeed all metabolic processes, hark back to that ancient pattern."

Fascinating though these speculations may be, it will be worth our while to backtrack to examine the assumptions we have made in arriving at these conclusions. First, we assumed a reducing atmosphere for the primitive Earth — an assumption that seems reasonable in light of the cosmic abundance of hydrogen. However, more and more researchers are questioning this assumption on paleogeological and geochemical grounds. Indeed, there seems to be a whole body of evidence which has been practically ignored in many discussions of the subject. A primitive atmosphere composed *predominantly* of methane and ammonia is in serious trouble when weighed against evidence from other disciplines, including geochemistry. For one thing, if the primitive terrestrial atmosphere was as extremely reducing as proposed, one expects geochemical evidence supporting it — evidence conspicuous by its absence. For another, neither methane nor ammonia could have existed in significant quantities for very long — methane because it so quickly transforms into more complex hydrocarbons, and ammonia because it would be rapidly broken down under the action of the Sun's rays unless there was an abundant continuous supply of it (and it is doubtful whether there could have been enough volcanos to outgas such enormous quantities of ammonia). Fortunately, however, these unsolved questions do not invalidate our previous discussion, since tholin-like compounds have been produced using a wide variety of gas mixtures, including some that do not require large amounts of either methane or ammonia.

Our next critical assumption was that life could have subsisted on the accumulated organics in the primitive ocean until competition for resources led to the evolution of more complex metabolic pathways. In a paper delivered in 1982 at the Planetary Volatiles Conference in Minnesota, Boston and Stoker reported that while their bacteria have grown on extremely low concentrations of tholin, some doubt still remains whether available sources of carbon and energy could have provided sufficient tholin to make the scenario work.

Finally, we have assumed that the bacteria metabolizing tholin in the laboratory at the University of Colorado can give us an indication of how early life might have responded to the presence of tholin on the primitive Earth. Though we have no guarantee that this is the case, the arguments in its favor are quite plausible. Bacteria are very simple organisms, generally believed to have some of the most primitive evolutionary antecedents. The fact that anaerobic bacteria, which do not require (or even *like*) free oxygen, have been found to metabolize tholin strengthens the case for a spontaneous generation of life in the near-absence of oxygen — an absence still agreed upon by virtually all researchers. Granted, the evidence for protobacteria on the primitive Earth is circumstantial; but as Thoreau is reputed to have remarked, "some circumstantial evidence is very strong, as when you find a trout in the milk."

So we see that the reasoning, true to exobiological tradition, is nowhere conclusive. However, these questions are part of what comprises the excitement of the field, in the same way that the uncertainties in other areas of astronomy add to their fascination.

"Jupiter Jars"

The Tholin Biology Experiment, which is really a rather elaborate extension of the simulation performed by Sagan and Khare at Cornell, was originally the idea of Boston herself, who wrote to Sagan requesting tholin to use in a microbiology experiment she had been contemplating for years. Known to its friends as the "Jupiter Jars" project, the TBE is the natural sequel to the "Mars Jars" project, which Boston oversaw the year before. Boston is a biologist with years of experience in experimental biology, terrestrial and other; many of her research experiments were of her own conception, and most are less exotic than the TBE.

While the Khare-Sagan experiment at Cornell simulated only the chemical processes that might go on in the jovian atmosphere, spectroscopic observations of Jupiter support it and reveal many of the same kinds of organic compounds seen in the products of their experiment. While it would be desirable to perform variations on this first tholin biology experiment — and the TBE suggests an endless number of follow-up experiments — funds have thus far not been available.

(The preliminary results were obtained through frugality and dedication on the part of Boston and Stoker, and the assistance of a small group undergraduate students, including myself, acting as everything from dishwashers to laboratory assistants to literature searchers. The generosity of Drs. Khare and Sagan in their contribution of tholin greatly reduced the time and cost of the biology experiment, and the experience that they brought to the project through their collaboration was invaluable to its success.)

Boston and Stoker obtained bacteria from soil samples from Rocky Mountain alpine regions, as well as tar sands from a natural oil slick in Utah; the anaerobic species came from oxygen-poor pond mud. The sites were chosen for their probability of containing hardy bacteria with a reasonable chance of metabolizing tholin. *None* of the species isolated on the successful plates were particularly exotic.

The bacteria were first cultured in a medium enriched with tholin, to encourage tholin metabolizers. Promising organisms were then transferred into a pure culture with tholin as their sole carbon source. At every stage of the experiment, controls were maintained and precautions taken to be sure that the result was not coincidental. Since there are bacteria which can live off light, we ran the experiment in the dark. The organisms given tholin grew, whereas control cultures did not.

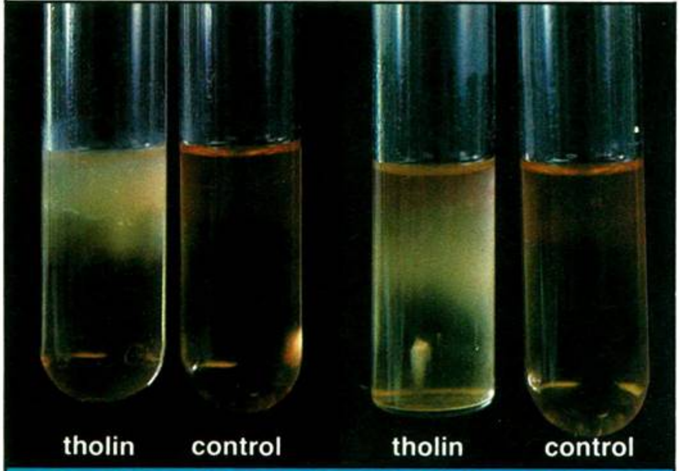
Growth rates were considerably higher for the aerobic than for the anaerobic bacteria, as is fairly typical in microbiology;

in both cases it was clear that the bacteria were using tholin as a source of energy or carbon or both.

Once a culture showed tholin metabolism, the bacteria were diluted into manageable populations and examined under a microscope. The anaerobes, taken from lake bottom mud and cultured in an anaerobic chamber, were easily recognized as such. The aerobes identified were "common garden varieties" of soil bacteria.

Experience in a microbiology laboratory may be the only way to come to a true appreciation of just how easy it is to contaminate a sample — or a human, or a planet. Simply touching an instrument to an unsterile surface or waving it in the air is enough to contaminate it. I quickly came to respect the ingenuity of these tiny creatures in finding new abodes for life.

The fact that microbes not requiring oxygen have metabolized tholin, albeit slowly, has two serious implications for planetary science. The first is a definite plus for exobiology, since it lends credence to theories of the origin of life in a reducing environment and models that have been proposed for an indigenous biology on planets like Jupiter. The second, more sobering, ramification involves the possibility of terrestrial microorganisms surviving on such planets.



Bacteria (milky white material) grow in cultures with tholin and control cultures without tholin. Left pair of test tubes contain facultative anaerobic bacteria, which can use oxygen if it is available; pair on right contain micro-aerophiles, which like a small amount of oxygen. Photo courtesy P.J. Boston.

The Dark Side of Galileo

Speaking strictly from the standpoint of planetary physics, the Galileo mission will provide critical data about Jupiter — information about the horizontal and vertical motions of the atmosphere, more precise spectroscopic measurements of the top layers of the atmosphere, further data concerning the gravity and magnetic fields of the planet, and on-site analysis of the composition and structure of the atmosphere (see "Galileo: The Mission to Jupiter," ASTRONOMY, February 1982).

Let's look back over NASA policy with respect to every probe heretofore sent to another planet. Until now, NASA has maintained a strict policy of planetary quarantine, in a laudable effort to avoid repeating the mistake of the Old World settlers of the Western Hemisphere, who unwittingly brought disease and pestilence with them to the lands they explored. From the beginning of planetary exploration, Carl Sagan has been one of the prime movers behind this policy.

The first landers sent to the Moon were subjected to rigid sterilization procedures. Only after scientists had established beyond what was considered any reasonable doubt that nothing could live on such a dead body as the Moon were quarantine procedures abandoned on later probes. Thus the Surveyor landers were sent unsterilized to what was confidently believed to be a wholly inhospitable environment. Almost three years after the Surveyor 3 craft arrived on the Moon, Apollo 12 landed next to it. Astronauts removed the camera, cables, and scoop and returned them to Earth, where they were dismantled in a clean room. Deep within the cabling of the camera wires were living, active terrestrial bacteria — in an instrument that had been in a supposed purgatory for three years, with no light, no food, and no water, in temperatures varying from −200°F to +300°F. Though contamination of the camera cables in the clean room cannot be ruled out, the evidence suggests strongly that microbes can, indeed, survive in hostile environments.

The Viking landers on Mars are perhaps the shining example of NASA's efforts to preserve planetary quarantine. In that case it was especially critical, since stringent measures had to be taken to prevent contamination of the Viking biology experiments and their search for martian life. In spite of these efforts, Terry Foster and Luther Winans of Hardin-Simmons University demonstrated that the Viking probes probably contaminated the Red Planet with psychrophilic (cold-loving) organisms which had been overlooked in sterilization procedures.

This sobering fact gives an inkling of just how rigorous spacecraft sterilization must be if it is to succeed. As planetary exploration continues, we'll surely learn to do it properly and with a minimum of expense — that is, if we care enough about our actions, seen or unseen, toward our neighboring planets and any life that might exist there.

Planetary quarantine requirements have been a thorn in the side of planetary scientists, since the heating involved in sterilizating spacecraft has been responsible for more than one failure of the electronics on which spacecraft depend — this happened, for example, with the Block II Ranger spacecraft, precursors to the successful lunar missions. Sterilization of a probe implies completely changing the electronics that would otherwise be used. An electronic system designed to withstand the rigors of sterilization is more costly than is generally convenient in a business usually strapped for funds in the first place. In view of the financial considerations, NASA's policy in the past has been as surprising as it was praiseworthy.

In 1967, an international agreement was reached regarding planetary quarantine by the Committee on Space Research (COSPAR). That treaty, to which the United States is a party, requires that the probability of contamination of planets — including Jupiter — be kept less than one in a thousand during the period of biological exploration, roughly 1974 to 1994. To be on the safe side, NASA has tried to limit the probability of contamination by an interplanetary probe to less than one in a million. And the Galileo probe, according to NASA, meets that requirement.

The loophole lies in the wording of the COSPAR accord, which is based almost exclusively on probabilities of quantities that no one is certain about. The method of estimating probabilities in arriving at quarantine requirements was called into question by Margulis *et al.* in their 1977 paper, ". . .General Principles of Planetary Quarantine Leading to an Assessment [for the Outer Planets]": "We recommend the abandonment, in principle, of any approach which assigns numerical probabilities to qualitatively unknown phenomena." And the Space Science Board, in its 1978 *Recommendations on Quarantine Policy* [for the outer planets and their moons] laments the uncertainties involved in estimating the probability of growth of terrestrial bacteria on Mars and the more distant planets: "Our ignorance as to the ranges of physical and chemical environments on planets and our knowledge that terrestrial organisms possess amazing abilities to function in a wide variety of terrestrial environments combine to make the estimation of [the probability of growth] vexatious and inexact."

Though it may be possible to sterilize the parachute . . . there are no publicly-announced plans to do so at present.

Though scientists are obviously sincere in their attempts to assign realistic probabilities to phenomena that are still too poorly understood, the wording of the treaty leads to a curious conclusion. When estimating probabilities of phenomena that nobody knows anything definite about — such as the survivability of microbes in a place as unknown as the atmosphere of Jupiter — it is easy (and none too informative) to insert arbitrarily high or low figures into the equation to suit one's preference, conscious or unconscious. Hence one could "legally" contaminate any planet by estimating the probability as "nil," in which case the requirements for planetary quarantine would also be nil.

The Galileo mission is the first recent instance in which NASA has designed a probe without making an effort at planetary quarantine. Though preliminary studies to examine quarantine precautions for the probe were begun at NASA-Ames Research Center, they were abandoned when internal NASA policy on planetary quarantine procedures for the outer planets shifted radically — and as money for the exploration of the solar system ran low.

Following the ambiguous results of the Viking biology experiments, the results of which are widely interpreted as negative (see "The Search for Life on Mars," ASTRONOMY, December 1983), a distinct shift in priorities has occurred among planetary scientists. Until that time, they seemed willing to submit probes, albeit at the insistence of exobiologists, to sterilization. The prevalent feeling today was expressed to me by one leading expert in planetary science who complained impatiently about the constant criticism from exobiological environmentalists which makes it so difficult for scientists like himself to "get any work done."

In the aftermath of the Viking biology experiments, Lynn Margulis, a highly respected biologist, and her co-workers published "Limitations to Growth of Microorganisms [on the outer planets]." The paper concludes that the atmospheres of the outer planets are so unlikely to support any kind of terrestrial life that it is a waste of time and money to worry about contamination of those planets in future missions. Though many reasons were cited for this conclusion, among the most emphatic was the interdependence of terrestrial life.

On Earth, where life has been evolving for billions of years, adapting to increasingly complex environmental conditions, all organisms depend on the life processes of other organisms. While this contention has much to recommend it with respect to life on Earth, the assumption that we now know enough about the behavior of life in radically different conditions, or about the atmosphere of Jupiter, to *rule out* the possibility of survival of terrestrial microorganisms on Jupiter is unfounded.

It is especially relevant to note that in drawing their conclusions, Margulis and her co-workers relied on the model published by S.J. Weidenschilling and J.S. Lewis in *Icarus* in 1973, which they believe "maximizes favorable conditions for the support of life." But the bottom line of Weidenschilling and Lewis's paper reads, "all computed cloud structures represent planetwide average conditions; *entry probes may encounter very different local conditions.*"

Exactly what kind of "different local conditions" the probe will meet is nowhere made clear, for the simple reason that *nobody knows*. There are two reasons for this uncertainty. One is the limitations of the aiming of the probe. Yeates and Clarke explain: "Since the probe has no maneuvering capabilities of its own, its targeting at time of release must be extremely accurate. If all goes well it will enter the jovian atmosphere with a latitudinal error of less than 800 kilometers." While this may be, as they assert, "excellent marksmanship indeed," it is obviously not precise enough to help us much in determining local conditions the probe will encounter. The second reason for uncertainty here lies in the general state of ignorance about conditions within that atmosphere, even if we knew precisely where the probe would enter it.

Yet it is precisely such entry probes that are at issue in the discussion by Margulis and her colleagues. Hence this enormously influential paper discussing the probability of survival of terrestrial contaminants on the outer planets draws critically on assumptions that do not hold for the entry probes under discussion.

The Space Science Board of the National Academy of Science drew heavily on Margulis' paper when it published revised planetary quarantine policy for the outer planets. They concluded that conditions on Jupiter and the other planets, including their moons, are so harsh that the probability of growth of a terrestrial contaminant is considered to be nil, and that no sterilization procedures beyond "clean room" policies (intended only to reduce the number of microorganisms on a probe, primarily to protect the hardware) are necessary for missions such as Galileo. They based this conclusion on the belief that ammonia will be present in intolerably high concentrations, that the combination of environmental stresses will be too much for even the hardiest of microbes, and the assumptions that "the existence of proper nutrients is unlikely," and that "convection to pyrolytic temperatures is likely."

The mixing ratio of ammonia on Jupiter has been estimated as 10^{-4}, meaning that one molecule in 10,000 will be an ammonia molecule; there are believed to be aqueous ammonia clouds in which the concentration would undoubtedly be higher, and where the alkalinity would be far too high for any known terrestrial organism. (Most of the other molecules would, in any case, be molecular hydrogen.) A mixing ratio of 10^{-4} is not forbidding in light of the fact that ammonia is not the "killer gas" it is often thought to be. Indeed, many organisms depend on ammonia for their survival. Ironically, determining the concentration of ammonia in Jupiter's atmosphere is part of the rationale for sending the probe in the first place.

Engineers prepare the Galileo probe for vibration testing. It will be released from the main spacecraft 150 days before Jupiter encounter and will enter the jovian atmosphere at 48 kilometers per second. NASA photograph.

The belief that the "combination of environmental stresses" will wipe out even the toughest of terrestrial microbes is also questionable. Life has been found in even the most unlikely of habitats — from the mouths of active hydrothermal submarine vents to inside the cores of functioning, active nuclear reactors, where *Micrococcus radiodurans* reportedly thrives. Furthermore, the temperature life is known to be capable of withstanding has doubled following the discovery of organisms that survive temperatures of 350°C.

Scientists have consistently underestimated life's tenacity; past experience implies that the only way to be sure whether a given organism will survive a given hardship is to subject it to that stress and watch its reaction. In light of this, it seems quite surprising that, in the words of Margulis and her co-workers, "the assumption is that terrestrial organisms borne on spacecraft *cannot* survive until it is proved that they can do so."

In other words: to determine whether an unsterilized spacecraft will contaminate Jupiter, we should send an unsterilized spacecraft and find out!

The reference to "convection to pyrolytic temperatures" is intriguing. The jovian atmosphere is highly convective, constantly churning in response to incompletely understood forces within the planet's depths; its temperature increases with depth. The assumption is that convection would transport microbes down to temperatures where they pyrolyze, or are destroyed by heat. Since the size of the convective cells is unknown, however, nobody can say how deep the convective currents would transport particles such as microbes or whether, in fact, bacteria would even reach pyrolytic depths, or how long the jovian currents would take to carry them to these hellish depths. Could it be long enough to allow bacteria to reproduce?

". . . the existence of proper nutrients is unlikely . . ."

The extent of our ignorance on this last question is best illustrated by the fact that at the Division of Planetary Sciences meeting in 1982, an informal poll of a half dozen of the top researchers of the jovian atmosphere revealed that most of them wouldn't venture an estimate. The best guess I have yet received is anywhere from one month to ten years — plenty of time, in theory, for microbes to get started populating Jupiter, since in the laboratory they are observed to double their populations in periods ranging from one hour to one day.

While it is believed that the high hydrogen concentration in the jovian atmosphere may inhibit the survival and growth of many (but not all) microbes, there has been very little experimental study. We should not assume anything, especially in the light of past miscalculations of the survivability of microbes.

Another questionable assumption made in revising planetary quarantine policy is that "the existence of proper nutrients is unlikely." The scientists drawing up the National Academy of Sciences recommendations were presumably thinking partly in terms of vitamins and minerals, and partly about food. In light of new experimental data provided by the TBE, tholins, which we now know some bacteria can use as food, may be available. Nobody knows how much tholin might be available to any bacteria in the jovian atmosphere, or for that matter, anything specific about the conditions they are likely to meet.

What is at issue is much more than possible contamination of Jupiter.

Last year a proposal was submitted within NASA to launch an identical probe to Saturn — bugs and all. The latest word is that funds are too short to allow NASA to send the proposed duplicate, but the director of mission analysis for Project Galileo says, "that doesn't mean we wouldn't like to." Furthermore, in a recent publication called "Planetary Exploration Through Year 2000: A Core Program," many missions to outer planets are proposed, including a Titan lander. Where the outer planets are concerned, the NAS recommendations will undoubtedly be called upon to dictate planetary quarantive requirements; if they are applied as they have been to Jupiter, then all the outer planets are fair game. Furthermore, the core program stresses the need for reduction of costs; cost reduction efforts will probably include the reduction or elimination of expensive planetary quarantine procedures. Clearly, now is the time to settle the issue once and for all.

To alleviate the ambiguities built into the numerical approach to planetary quarantine, a new "Planetary Protection Plan" has been proposed within NASA. This document begins by throwing out the quantitative approach to planetary protection entirely. While this is undoubtedly a step in the right direction, their alternative is depressing — not to say frightening. It is even less specific than the numerical approach, and reduces cases like the Galileo mission to one of properly documenting the crime; it turns to scientific opinion to determine biological protection strategies.

Now let's look at some other questions commonly raised by those new to the issues of planetary quarantine and spacecraft sterilization.

Contrary to popular belief, exposure to the vacuum of space does not kill bacteria. It has been experimentally established that many bacteria survive spaceflight. The main effect of the vacuum of space is to freeze-dry them, in much the same way that they are lyophilized (freeze-dried) in the laboratory to preserve them in the best possible condition for long periods of time. Many bacteria form spores when the going gets tough, entering a dormant phase until conditions appear more hospitable, at which time they reactivate as if nothing had happened.

Though other methods have been proposed to sterilize spacecraft, the most feasible technique for many spacecraft components remains the dry heat procedure NASA has been using until now.

Thus, a number of factors require that spacecraft be built from the beginning in ultra-clean conditions with planetary quarantine in mind; it is not something that can be slapped on a probe at the last minute. Unfortunately, the Galileo spacecraft have already been built without any attempt to significantly reduce the number of bacteria in and on the probe.

Direct ultraviolet light from the Sun is, of course, detrimental to the health of microorganisms, and bacteria exposed to direct ultraviolet irradiation will surely be destroyed. It should be remembered, though, that it takes very little to shield an organism the size of a bacterium. One dust particle is sufficient.

There is, however, another efficient sterilization mechanism for the exterior of interplanetary spacecraft. The friction of entering a planetary atmosphere heats the outer surfaces of a craft hot enough to burn up most, if not all, microbes clinging to the outside. Between the ultraviolet and the friction, any microbe on the exterior of an interplanetary craft will probably be wiped out. It is the buried burden — the bioload hidden *inside* the complex machinery of spacecraft — that is much more difficult to destroy.

In the case of Galileo, stowaway bacteria will remain inside the probe as long as it remains intact because as the probe falls into regions of higher and higher pressure, the atmosphere will leak in, but nothing will leak out. At some depth, however, the probe will be either burned or crushed. Asked whether the probe would be crushed or burned *first*, an engineer at Ames Research center who worked on the preliminary planetary quarantine studies could only say, "That's a good question."

From the standpoint of minimizing contaminants released in the jovian atmosphere, pyrolysis (burning) would be the ideal fate of both the probe and its burden of "bugs." But if the probe's fate is a slow crunch, bacteria in viable condition could escape. Whether they could adapt to the environment they will encounter after their long dormancy remains an open question.

Lynn Margulis and her co-workers concede that "one could not totally exclude the possibility on the outer planets of oases becoming hostile slowly enough and under the proper conditions to permit vegetative cells to convert to spores." Nobody can reliably claim to know at what level in the jovian atmosphere this might occur, or whether spores might then be convected upward in the atmospheric currents.

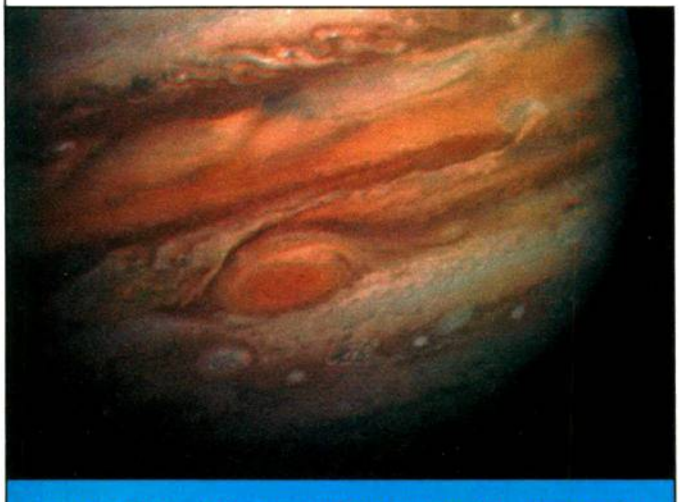
". . . convection to pyrolytic temperatures is likely . . ."

The probe, however, is not the real problem. What will be the fate of the parachute deployed in the very upper levels of the atmosphere to slow the probe's descent? The parachute will be protected during the long trip to Jupiter and the treacherous transit of the jovian radiation belts by a heavy heat shield designed to protect the instruments aboard the probe. The estimated radiation dose in the descent module will be 75,000 rads — well below the 300,000 to 400,000 rads required to effect a 90% kill of most microorganisms, to say nothing of *Micrococcus radiodurans*, which can withstand a million rads with no reduction in the viable count.

The parachute will be made of dacron, which — when one takes into account the many fibers in the estimated ten square meters of fabric — will provide an enormous surface area for bacteria to cling to. And the chute will make its descent slowly, after having been thoroughly shielded from the friction, ultraviolet light, and energetic particles likely to destroy the microorganisms which choose less secure spots for their sojourn.

All current models of the jovian atmosphere assume pressure increasing with depth, with corresponding increases in temperature. Between the bitter cold and low pressure at the cloud-top level, and temperatures and pressures great enough to force hydrogen into a metallic state, there exists a layer in which the temperature and pressure might be hospitable to terrestrial life. This layer, according to both ground-based and Voyager data, exists at a level which the Galileo probe will surely reach.

At present, no attempt at sterilization is planned for the probe. Though it may be possible to sterilize the parachute — thereby removing 50% of the microbial burden — there are no publicly-announced plans to do so at present.



Jupiter, the largest planet in our solar system, has an atmosphere consisting largely of hydrogen and helium, with smaller amounts of methane and ammonia, and minute amounts of more complex compounds. NASA photograph.

The unpleasant truth is that the only way to achieve a truly clean probe is to construct it again from the start. A couple of years ago I asked a scientist in a high position of responsibility what would happen if somebody decreed that the probe must be sterilized; he said: "It would cancel it."

In the case of a planet where there may be a pre-existing ecology, the ethical ramifications of contamination are obvious. Though an indigenous biology on Jupiter has not been ruled out, that is just one more unanswered question about the planet to which we may be sending our bacteria.

Suppose, in a few decades, funds become available for serious exobiological investigation of the solar system, and Jupiter is targeted in a search for life; and suppose further that life is found. If the Galileo probe is sent according to the present plan, there will be no way to determine with certainty whether life found there is our own bacteria or indigenous to Jupiter. Life evolves when subjected to environmental stresses; hypothetical contaminant organisms left by the probe might well have mutated beyond recognition.

Even assuming their DNA structure will remain recognizable — and this is by no means certain — it will not provide a certain indicator that the life we find is our own. We have no other examples of life on which to base such a judgment. If jovian life happened to have DNA structure similar to ours, we might never be able to distinguish it from our own mutated bacteria. Regardless of whether any terrestrial organisms survive jovian conditions, we will have destroyed a pristine environment, and will never know whether the jovian life is truly jovian or adapted terrestrial life.

Scientists at NASA are clearly sincere in their belief that nothing could possibly survive the rigors of transplant to Jupiter via the Galileo probe. All those with whom I have spoken have been polite and helpful in response to my questions, but if they shared my apprehensions, it was well concealed.

Until now, NASA has maintained a strict policy of planetary quarantine.

Admittedly it is likely that any anaerobic bacteria which reactivate in the jovian atmosphere will discover that they have met their nemesis. But this likelihood is not so high as to constitute certainty; how can anything be assumed certain in the face of profound unknowns? The problem is not that the survival of terrestrial bacteria on Jupiter is likely, but that we do not know enough to say how unlikely it is.

Though the words come out of the mouths of NASA scientists, perhaps the burden of responsibility for their altered, more casual attitude toward planetary quarantine of late lies not with the scientists, but with others. It is our elected political representatives and the appointed policy makers — through the deceleration of the "Golden Age of Planetary Exploration" — who have fostered penny-pinching among researchers struggling to continue a program of exploration in a field where an irreducible minimum of funds is mandatory to do the job correctly.

Galileo is now the keystone of the American planetary exploration program. Apparently few scientists are willing to suggest, under these circumstances, that ethics take precedence over expedience; yet that is what I feel we should do. Unpopular though it may be, some attempt at sterilization or even outright cancellation of the probe component of Galileo, is precisely what I advocate — speaking only for myself, as a journalist.

Would it not also make better sense — scientifically — to take data from the Galileo orbiter to prepare for the day when we can undertake exploration of the jovian atmosphere without contamination? Is it necessary to take the chance that premature deployment of an unsterile probe might render future investigations ambiguous? Is an hour's data from the probe worth the potential destruction of the pristine jovian exobiology laboratory?

Conclusion

One thing is clear about the experiment conducted at the University of Colorado: it has raised questions. Questions are the lifeblood of scientific progress. They suggest new avenues for research, even as they touch many different problems, from the origin of life to the scientific propriety of conducting an uncontrolled experiment with Jupiter.

The "Star Tar" experiment answered only one question directly: "Can terrestrial bacteria metabolize tholin?" The answer is yes. But just as the Urey-Miller experiment raised more questions than it answered, the tholin biology extension of that continuing quest into our origin could quite possibly become a benchmark for critical studies into exobiology and the origin of life — provided we heed its more subtle implications and preserve the solar system now against the time when we can ask those questions in a way that will not forever destroy the answers.

Linda Strand is a freelance science writer specializing in exobiology and the search for extraterrestrial intelligence. She is a member of the Colorado University Space Interest Group.

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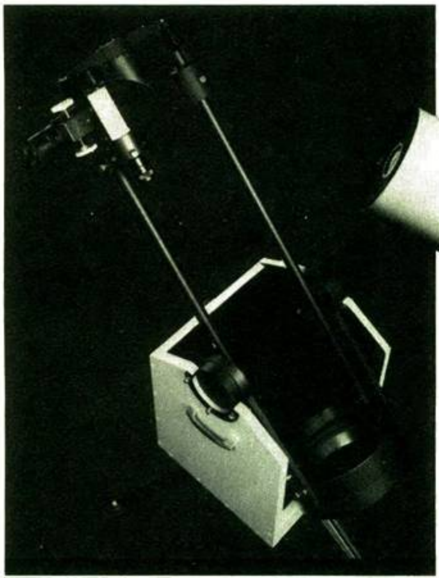

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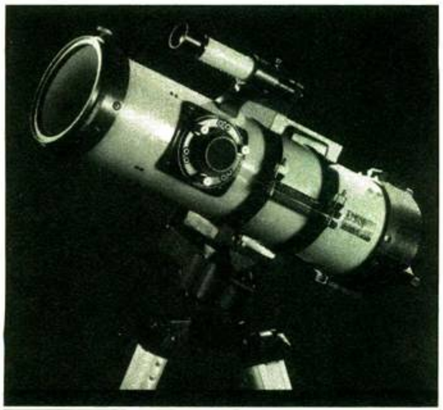

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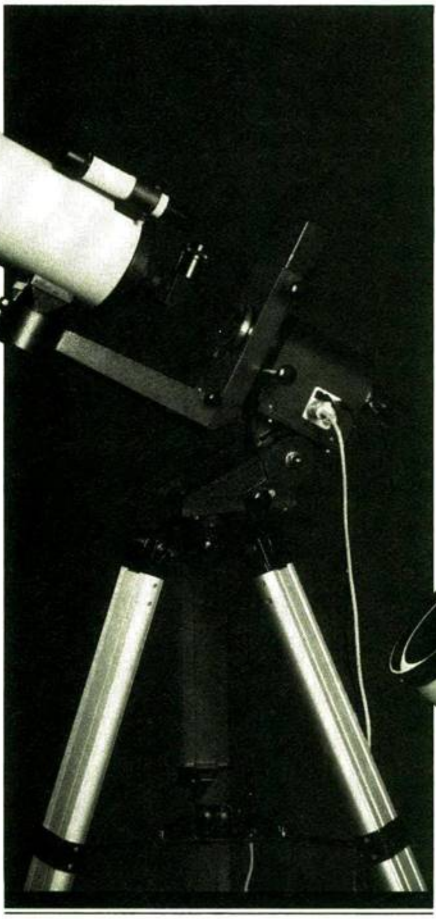

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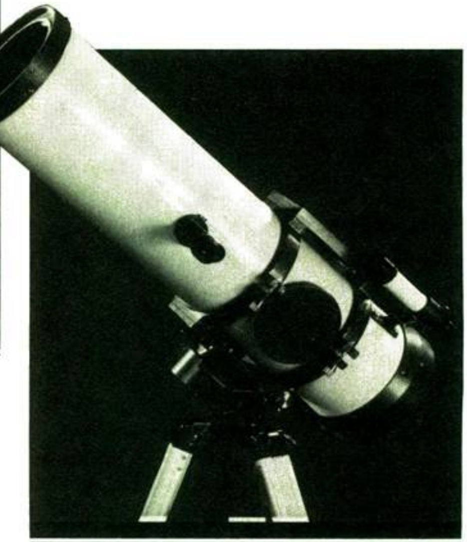

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My Son the Astronomer

Sometimes I look at my almost-five-year-old Scott and imagine myself at his age. Being a proud dad, I recognize some of my qualities (good and bad) in him already. My unfulfilled hopes and dreams ride with him, even though I know he will be his own person. Like most little boys, he tries hard to emulate his dad. Like most dads, I try hard to let him.

Scott had often approached me when he was very young about looking through the telescope. If you've ever tried it, you quickly realize very few toddlers are able to do so because they lack the coordination to put their head and eyes in the right place at the right time. If allowed to practice, a child should begin to be able to do this quite adequately by about four years of age. Several times he had peeked through the scope but I was never sure he was really looking at anything — besides, kids' attention spans aren't very long. But when we peeked through my microscope at a blood smear and he announced to me that the blood cells "looked like donuts," I felt he could begin to enjoy using the telescope.

I certainly remember my own first view through a telescope; the telescope was a small refractor and the view was the Moon. To this day I remember the electric thrill. I was absolutely thunderstruck; from then on I never really lost that awe and interest.

The years have quickly gone by since that first view. Part of getting older is developing a slightly jaded view of new experience; the childlike innocence and freshness have long since been engulfed by technicalities such as focal ratios, optical design considerations, new eyepieces, and the like. But every so often a glimmer of that early wonder surfaces and reminds me of what this hobby really means.

My 8-inch reflector on a Dobsonian mount is the perfect height for an adult, but not for a youngster only three feet tall. When I told him it might be hard for him to see comfortably, he replied with the impeccable logic of an almost-five-year-old, "Well, let's build one for me — a small one. I'll use the big one when I get bigger!"

Now at first this sounded fine; we would build a little reflector for him in the basement. Problem was, I had been saving for this new eyepiece and didn't want to spend a great deal of money if it could be avoided — no, to be honest, I didn't want to spend *any* money. But he had asked me so sweetly and with such childlike sincerity (read "hounded me constantly"), that I had to figure out a way to make us both happy. The solution was quite simple and a good compromise.

> ***. . . little kids aren't particularly intrigued with deep-sky stuff . . .***

First, it became obvious to me that any instrument with a focal length much longer than about 30 inches would be too unwieldly. Second, little kids aren't particularly intrigued with deep-sky stuff; the Moon and planets are about all they want to look at. It's also about the maximum a youngster can comprehend on his limited space-distance framework.

If you haven't figured it out by now, a 3-inch f/10 reflector fills the bill just about perfectly. The optics are inexpensive even if purchased new, and very often you can find them kicking around ATM shops. I bought Scott's, quite used, from a friend for two dollars. The aluminizing job wasn't perfect, but it was adequate. The mount was made out of a circle of plywood using bent paper clips for the mirror clips.

Three bolts and springs at the hardware store along with some wing nuts completed the collimation adjustments for the "cell." Half-inch angle brackets mounted to the plywood edge and to the inside of the tube support it perfectly. I found that a piece of 4" I.D. PVC drain pipe made a perfect telescope tube. Since I only needed 30 inches, the supplier gave me the piece for nothing — it was a cutoff remnant.

Although I planned to build the focuser as a slide tube type, I broke down and purchased an inexpensive rack-and-pinion focuser with an attached single vane diagonal holder. This proved to be a wise decision, because besides the cosmetic appeal, it is much easier for a child to manipulate this type than a slide tube type. The mount is a classic Dobsonian scaled way down to size. It was built from scrap, works like a dream, and is easy for him to use.

An old viewfinder scope, several coats of red spray paint for the tube, and Scotty's Scope was completed. I had let him help me drill the holes, measure the exact f/ratio of the mirror (actually f/9.2), and do some of the painting. Not only did he feel he had an integral part in the building of his telescope, he gained a better understanding of how it works. The therapeutic value of a father-son project shouldn't be underestimated, either.

His first view of the Moon with his scope brought back a flood of memories I thought had been buried years ago. Had I been this excited with the flush of new discovery? Gradually,

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I realized with dawning comprehension that this was exactly what my hobby was all about! My nostalgic reverie was interrupted by a flurry of questions about craters and how they got there — followed immediately by my trying to reassure him it doesn't happen on Earth very often. Our observations have provided hours of talk and looking at pictures in books. He has become the neighborhood authority among the five-year-olds about telescopes and the Moon, and is fiercely proud of his little instrument.

His wide-eyed look and exclamations of amazement and wonder made this project much more important to me than he will even know. Perhaps one day his child will say the same thing to him, and then he will realize what I have felt. But the best part of the whole thing was when he came up to me after we had looked at the Moon together for the first time, put his arms around my neck, and said, "I love you so very much, Daddy . . . thank you."

Bryan P. Shumaker
West Bloomfield, MI

Frank Melsheimer: Dr. Telescope

Down below, the young man on the large Bridgeport milling machine is hogging out a thick piece of steel. Another is turning a large steel disk on a lathe. The sound and smell of arc welding fills the air. In the front of the shop, several draftsmen are drawing mechanical parts, and the serious young lady is busy on an adding machine. Our interview takes place in a slightly cluttered electronics area upstairs.

ASTRO: Dr. Frank Melsheimer, could you tell me where DFM Engineering, Inc., got its name?

Melsheimer: We wanted a simple, easily remembered name, and came up with DFM. It's origin is quite obvious.

ASTRO: How did you get interested in mechanical engineering and its application to the design of telescopes?

Melsheimer: I was born in Alhambra, California, but while I was still quite young we moved to Fallbrook, California, which is not far from Palomar Mountain. My father, who was a mechanical engineer, took me along with him to see the 200-inch telescope four or five times. Perhaps this had a subtle influence, but I can't say that I was particularly interested in telescopes when I started working on my mechanical engineering degree at the University of California at Berkeley.

While finishing my Ph.D., I worked as an assistant professor, and one of my students, Jack Osborne, asked me to help him build a 6-inch telescope in the nice shop facilities there. I helped him with his — and built one for myself, too. Not long after this, the department chairman mentioned that Lick Observatory was having a problem with their 36-inch refractor.

ASTRO: What was the problem?

Melsheimer: The telescope shook if the wind got over 15 miles per hour. I drove down to Lick Observatory, looked over the telescope, and made a few suggestions. They liked my ideas and hired me. The pier consists of five or six large iron castings fastened together with about 200 bolts. After 95 years, all the bolts had loosened. With a big wrench, a pipe extender, and lots of "liquid wrench," I took care of that.

Over time, the load on the big push screws at the base of the pier had become very uneven, so I adjusted those, too. I added a preload in right ascension — with a cable and weight — and an air-cylinder preload on the declination tangent arm. These improvements increased the natural frequency of the telescope mounting and drive, and the telescope became usable in winds up to 25 miles per hour.

ASTRO: How did you come to design your first telescope?

Melsheimer: One day I was sitting in my office at Lick Observatory, when in walked a mild-mannered Clark Kent type — only with a beard. He introduced himself as Albert Merville, said he was from the Monterey Institute for Research in Astronomy, and that MIRA wanted to build a 36-inch telescope. He hastened to add that MIRA had been promised a finished 36-inch quartz mirror left over from the Air Force's balloon-borne stratosphere project.

Soon I found myself taking a trip with Bruce Weaver and Craig Chester, both from MIRA, to see the 31-inch telescope designed by Charlie Jones at Battelle Northwestern. Charlie Jones is one of the great telescope designers, right alongside such other greats as Russell Porter, Mark Serrurier, Bruce Rule, Bill Bostian, and Joe Nunn. Besides building such telescopes as the 107-inch at McDonald Observatory, Charlie Jones built other large things, such as the world's largest dump truck. Jones's 31-inch is a friction drive telescope with a Y-shaped fork of round cross section. I liked the design, but felt that I could improve on it.

This was how I came to be working for Lick Observatory during the day and designing a 36-inch telescope for MIRA on evenings and weekends. While I retained some of Charlie Jones's basic ideas, I essentially designed a totally new telescope. One of the many changes I made, for instance, was a rectangular cross section fork that had the Y shape on the inside, but came down straighter on the outside, giving it a larger cross section at the root of the fork. This made it extremely rigid — eliminating almost all the differential flexure.

ASTRO: So who built the MIRA 36-inch telescope?

Melsheimer: When my father died, my younger brother Tom took over the family steel fabricating business, and MIRA asked him to fabricate the telescope. Of course, I was in on it, too. In the end, I left Lick Observatory and worked full time on the MIRA telescope.

ASTRO: Can you tell me about DFM Engineering, Inc.?

Melsheimer: By then I knew I really enjoyed designing and building telescopes, so I set up DFM Engineering, Inc., along with my brother Tom, Scott Johnston, a former student, and my wife Kathryn. Our first job at DFM Engineering, Inc., was to design and prototype an 8-inch Schmidt-Cassegrain telescope. It took the four of us the better part of a year to complete the design, make the patterns and prototypes, and design a microcomputer-controlled mirror-making machine. Soon bigger work arrived, including an 18-inch telescope for the University of Colorado, a 24-inch telescope for Grinnell College, and a 2.4-meter telescope for the Michigan/MIT/Dartmouth Consortium Observatory, which will be on Kitt Peak. We also did a number of design studies.

ASTRO: I understand one of those was for a 5-meter telescope.

Melsheimer: Yes, the 5-meter design study was for Cerro Tololo Interamerican Observatory.

ASTRO: What sorts of things are important in designing telescopes?

Melsheimer: That's a good question, but (looking at his watch) it's lunch time now, and we all ride our racing bicycles for lunch. We usually ride about 14 miles up and down the hills. It takes about 43 minutes.

ASTRO: I'm surprised that all the DFM employees own and ride racing bicycles.

Melsheimer: That shouldn't be surprising. About 90 percent of the inhabitants of Boulder ride bicycles and ski. Besides, we make our own racing bikes here at the telescope shop — a fringe benefit for the employees. What's surprising is that we only have

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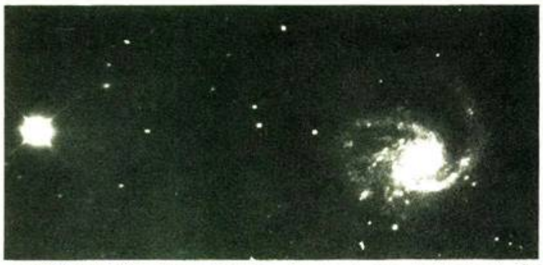

Spiral Galaxy NGC4254 (M-99) in Coma Berenices. The spiral arms of this lovely 10th magnitude galaxy can be seen in larger aperture telescopes. Photo by Dr. Jack Marling using a LUMICON EASY-GUIDER and 2415 film sensitized in a LUMICON Model 300 HYPER-KIT. 40 minute exposure, 24"f/6.5 telescope.

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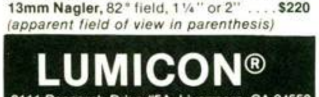

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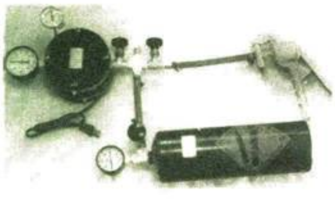

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5072, color slides from negs	36	$6.95
D-19 B&W Developer, 1 gal.		$5.95

one hang-glider enthusiast — less than our fair share here in Boulder.

*** 43 minutes later ***

Melsheimer (talking as he removes bicycle-racing apparel): O.K., back to your question about what is important in designing telescopes. There is more labor in a small gearbox you can carry around under your arm than there is in the giant fork that could crush you in an instant. The big pieces are inexpensive; it's the little pieces that cost the money, and it is here that design simplification really pays off.

Access for maintenance is vital. We design our drives so you can remove or replace an entire drive in only five minutes. Of course a really good telescope needs to be very stiff — giving it a high natural frequency. With a natural frequency of around 15 Hertz, our big telescopes are the stiffest in the business.

Electronics, cabling, and software are also important. Our electronics are mainly on easily replaceable cards. We design the telescope with cables in mind from the beginning and provide generous-sized conduits built into the fork and other parts so that the cables can be pulled through — connectors and all. Our software has evolved over several years and is now quite sophisticated.

ASTRO: I see that you try not to treat important things as afterthoughts. What is a typical DFM telescope like?

Melsheimer: We prefer to build fork-mounted equatorial telescopes because they have a minimum amount of counterweight and structure. The characteristic shape of our fork minimizes flexure, while the friction drive system provides high stiffness and zero backlash. Supporting the north end of the polar axle with two rollers on the drive disk allows a large-diameter polar axle to be used without the expense of a large bearing and bearing housing. The combination of these features gives a stiff telescope with excellent tracking.

ASTRO: A microcomputer is used to control the telescope?

Melsheimer: Actually, two microcomputers are used. They share the workload. One does the fine motion control while the other does the slewing, handles displays, and communicates with the other microcomputer, the telescope user, and any external computer. The control system makes corrections automatically, such as precessing coordinates, refraction, flexure, misalignment, etc. The telescope will automatically slew to coordinates or to an object stored in the internal library. The control system also handles the positioning of the observatory dome, and will do other fancy things — such as automatically trailing a star along the slit jaws of a spectrograph.

ASTRO: That really sounds nice! How much would one of your telescopes cost?

Melsheimer: We build high-performance telescopes at relatively affordable prices. Astronomical research can't be done if the instruments aren't affordable. Even though our regular telescopes are not intended for backyard astronomers and small colleges, they're still the most affordable telescopes in their class.

However, to accommodate those who want top performance from telescopes under 16 inches in aperture, we are developing a line of "small" mounts, with 15-inch friction disks. These are made with aluminum castings instead of being fabricated from steel. These mounts are not for the average amateur to put in his back yard . . .

ASTRO: . . . but they sound perfect for those who want to get into microcomputer-controlled telescopes!

Russell Genet
Fairborn Observatory

Amateur Astronomer as Gap-Filler

Some of the gaps we amateur astronomers fill are actually gaping holes.

In June, 1982, I roused a neighbor and her children from in front of the TV. It was a great night for viewing, and Jupiter was resplendent in the southeast. All four jovian moons were visible through my 4-inch telescope. The children were enchanted — a real one-on-one event, not a NASA poster. They repeated the names of the satellites over and over, and learned a little about celestial motion as the scope was readjusted.

When school began in September, the girl eagerly described this great adventure to her classmates during show-and-tell. But her teacher stated that someone must be mistaken — planets were not visible to the naked eye. They can only be seen through very large telescopes. The young lady tearfully related the incident to her mother. As soon as I found out what had happened, I wrote a note to the teacher, including drawings of Jupiter and the satellites as we had seen them that night. I gave the time and location for her to see the planet, too. I urged her to apologize to the child in front of her classmates. The teacher very graciously admitted her mistake.

Above our house there is a hill where I often go because I can see a sweep of horizon from far southeast to the northeast, and Ursa Major isn't blocked by trees. It is here in October that I greet Orion; and here, in Spring, that I view Jupiter and Saturn, Vega, Arcturus, and other familiar sky objects. One night as I zeroed in on Saturn with my telescope, a group of people walking down the road gave greetings, but continued on. Weren't they even curious about the telescope? I called to the disappearing group and asked if anyone would like to see the planet Saturn. All filed back, each taking two or three turns to see the wonderful rings. They all thought that both Jupiter and Saturn were stars, as well as Venus, gleaming in the northwest.

On another evening, following a dinner party, five couples including my husband and myself were walking toward our respective cars when I spotted Jupiter about south by west. Again, everyone thought this was a star. That Io, a mere satellite of another planet, had volcanoes, was a total surprise to them. I suppose I thought everyone had watched Carl Sagan's *Cosmos*.

It has always been one of my shortcomings that, once I am enthused about something, I expect others to follow. Some do. My husband, one of those brilliant souls who becomes quickly bored with most endeavors, was once content with the challenge of golf — until he idly began thumbing at random through my astronomy books. Although it took a while, he did give me a telescope, did have patience while I hit the books on astronomy and abandoned him to the TV set, and did eventually stop making comments about my mental state for scrambling out of bed at 2 a.m. to watch the Perseids. He now has an 8-inch telescope and his former 10 p.m. bedtime is often forgotten.

But consider this: while entertaining business associates at the Space Needle in Seattle — a wonderful place, where on a clear night the sky becomes a great planetarium dome — he pointed out the constellation Orion and described M-45 as he had seen it through his telescope. Yet the men had never heard of Orion.

Perhaps since the advent of bright city lights, TV, and spacecraft like Voyager, those with a fleeting interest in the sky have assumed that the stars and planets can be seen only from space, or that one needs a Palomaric telescope in order to see them. I shall never comprehend these gaps, but what a delight it is to fill them.

Marty Murphy
Redmond, WA

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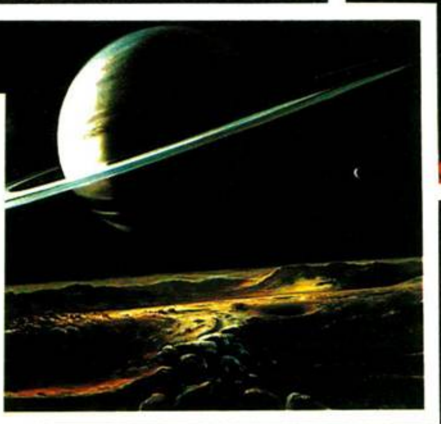

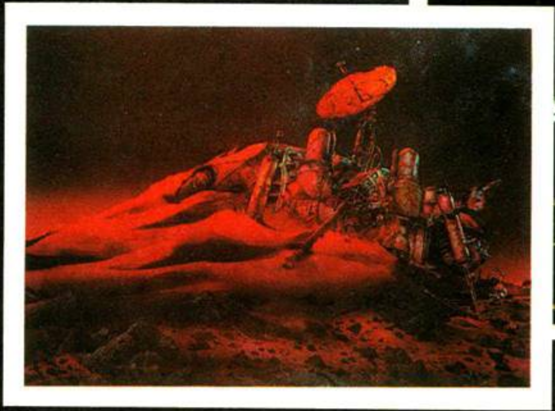

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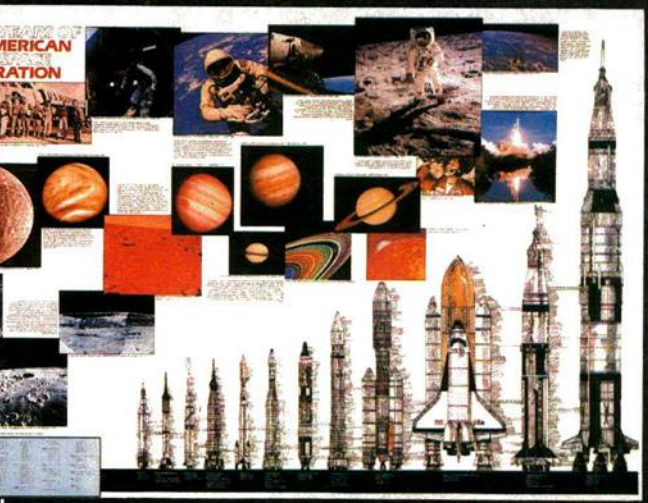

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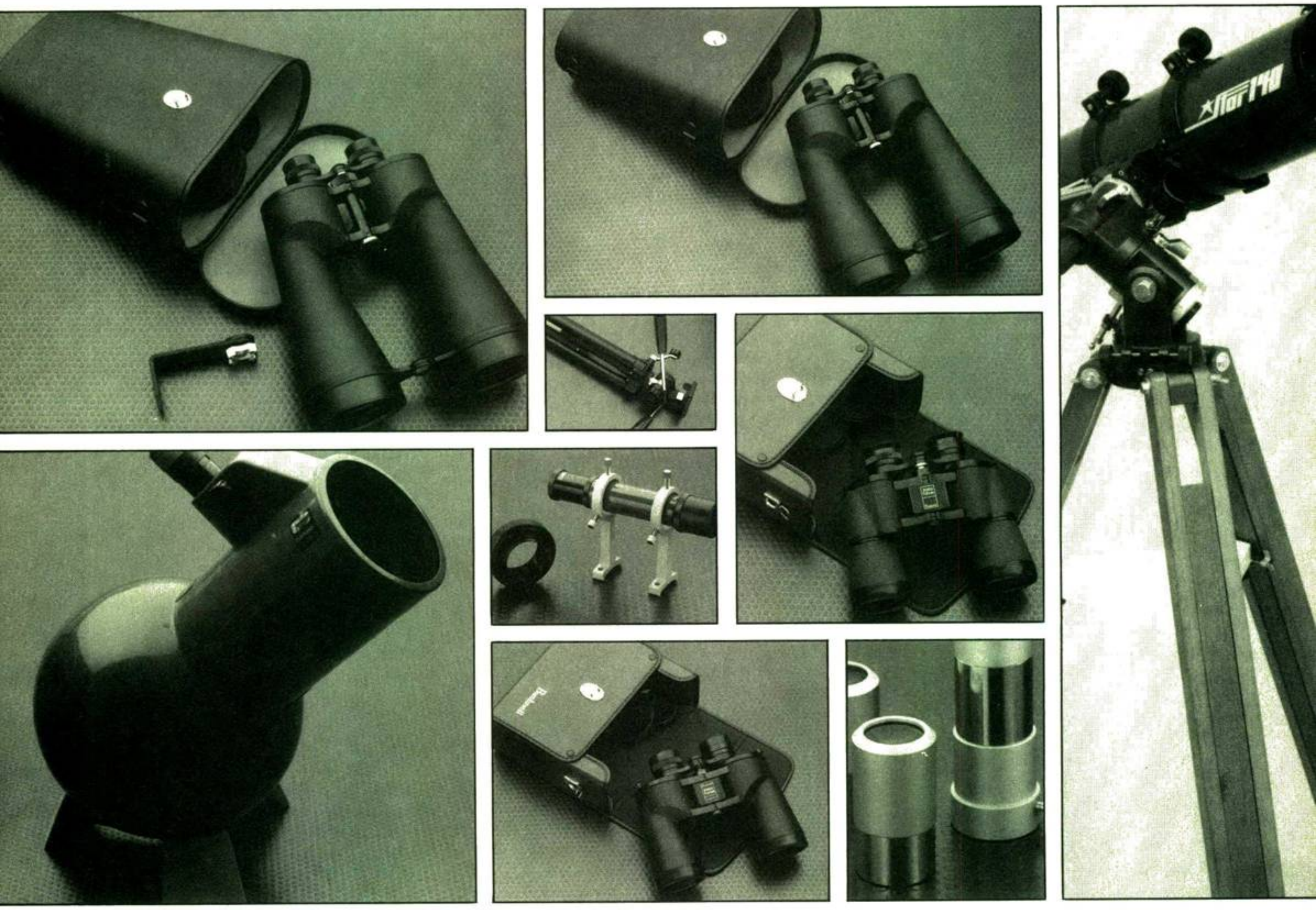

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ASTRONOMY

In Focus

A Fan Replies. . .

Sir / I disagree with Carol Rutter's article in the March Forum, "Hollywood Astronomy." The technology depicted by George Lucas in *Star Wars* conforms to Arthur C. Clarke's Third Law: "Any sufficiently advanced technology is indistinguishable from magic."

For the films *Star Trek* and *Star Trek II*, Dr. Jessco Von Puttkamer of NASA-Ames and Dr. Isaac Asimov were on hand to insure that the technology and science were correct and believable. For *E.T.*, Fieldtec, Inc. built a completely functional clean room. The room and equipment were absolutely correct.

Just because we know what our solar system's asteroid system is like does not mean we must regard it as typical. There are probably many different types and configurations of asteroid systems throughout our Galaxy. It would be extremely naive to deny the existence of the helter-skelter asteroid system shown in *The Empire Strikes Back*.

Did you notice the hangar bays seemingly open to empty space? What about the intercom commands of "Lower magnetic field on hanger bay 327"? It is just possible that a DC negatively charged super-intense electrostatic field could retain a breathable atmosphere in an airlock, on the other side of deep space vacuum, without using an airlock door. Think of the design, engineering, and mass savings of not having to use an outer airlock door!

Hyperspace is one of Rutter's buzz words. Many research physicists are trying to build a workable unified field theory for particle physics. Some of the most important descriptive terms in relation to the new particle information being discovered are symmetry, super symmetry, and super space. Certain particles have been caused to appear or cease to exist in particle accelerators. We do not know at this stage of our development whether hyperspace could exist. However, some other civilization "out there" may have already answered the question.

Star Wars is the first movie to capture what it may look like to exceed the speed of light. As a spacecraft accelerates toward light speed, the stars ahead coalesce into a ring and blueshift while the stars to the rear form a similar ring and redshift. After the speed of light is exceeded, it has been surmised the external view would be uniform gray or a blue-lighted tunnel. Mr. Lucas chose for his spacecraft to rapidly accelerate to light speed with the stars ahead shifting into streaks. During the Millennium Falcon's run to Alderaan in *Star Wars*, Han Solo's ship was shown racing down a mottled, blue-lighted tunnel while traveling at some multiple of light speed in hyperspace.

The use of bi-mode engines and null-gravity control for vertical takeoff and landing made very credible spacecraft capabilities in *Star Wars*. During flight through a planetary atmosphere, the fusion power pack used the atmospheric gases as fuel for the spacecraft's engines, making them into super ramjets. Once in free space, the engines switched automatically to internally carried fuel. The Rebel's X-wing, Y-wing, and B-wing fighters possessed faster-than-light-speed capability with limited range. Rebel A-wing and Imperial TIE fighters did not. Imperial TIE fighters used a solar power-enhanced ion drive with internal fuel supplement.

As far as I am concerned, any sentient being in the universe has the absolute right to self-determination, of free will, and to pursue their life in their own manner. Of course, you must not interfere in the rights of others in pursuing your own desires. George Lucas shows us a galaxy that is slowly becoming dominated by an Empire motivated solely by power and greed. A small band of Rebels, composed of hundreds of different species, races, cultures, and creeds, have allied together in a desperate attempt to stop the Empire. A race of small, furry sentient beings on a remote planet, that is picked as a pawn of the Empire, decides to throw in their lot with the Rebels, solely because the Rebels speak what is "true, right, and honest." The hunter-gatherer Ewoks never knew of the existence of other worlds until the arrival of forces of conflict. The Ewoks could have hidden and survived. Instead, they chose to risk and to win. Only the slave makes slavery possible.

In the final analysis, the Star Wars saga is very realistic, has a technology based in hard science, and depicts a way of life that may be very real in another time and another place. As you now realize, I think Lucas did a tremendous amount of research to back up his fictional technology, and I could go on and on. Remember, this is a world of "what if?"

Milton J. Schick
Tucson, AZ

Something from "Nothing"

Sir / Your article, "The Planck Era," by Sten Odenwald (March 1984), which concerns the appearance of matter and energy from the "primordial vacuum of space," filled me with admiration of the minds that can almost conceive the inconceivable. I'd like to see more articles of similar nature.

I thought that some of your readers might like the following quote from *Archy and Mehitabel* by Don Marquis, written in the very early twenties. Marquis wrote a newspaper column supposedly authored and typed by a deceased poet reincarnated as Archy, a cockroach. Mehitabel, an alley cat, was a reincarnation of Cleopatra and one of Archy's friends. Being a cockroach, Archy could not use the upper case shift key, so you must supply "caps" and punctuation.

". . . he i said is afraid of a vacuum what is there in a vacuum to make one afraid said the flea there is nothing in it i said and that is what makes one afraid to contemplate it a person can t think of a place with nothing at all in it without going nutty and if he tries to think that nothing is something after all he gets nuttier. . ."

Eugene Shafto
Staten Island, NY

Methane Ice Revisited

Sir / The letter from D.M. Graham in your March issue raises a point I continually have to clarify in my high school chemistry classes, and quite often in world-building sessions at science fiction conventions. Mr. Graham is only partially right.

It is common experience that solid and liquid water do exist together on this planet. Quite commonly the vapor form is in equilibrium with the other two, though probably more often it is actually below equilibrium pressure. The key point is that the *partial* pressure of the water vapor, not the total ambient pressure, should be considered for the phase diagram. On Mars, where the total atmospheric pressure is below water's triple point, liquid water cannot (at least at present) exist. The liquid region of the phase diagram is entirely above the triple point; solid and gas both extend below it.

The Earth condition could easily be true on Titan, except that the surface *temperature* seems to be a little high for solid methane. As Mr. Graham's letter states, methane snow or ice could exist on titanian mountains if any are high enough, and one can easily picture methane glaciers bringing the material to lower levels before it melts. Even silicate rocks, whose melting temperatures also rise with increasing pressure, will flow if the pressure becomes high enough; pressure-melting is not necessary for the creep phenomenon, though it certainly helps. The only real question about methane glaciers on Titan would arise from what depth of solid methane would be needed to provide pressure enough under that body's rather feeble gravity and methane's low mass density.

It is quite true that methane ice is denser than the liquid form of the compound; if bergs do calve from a methane glacier and remain visible thereafter, they must indeed be resting on the bottom of the sea or lake.

It has been pointed out that the actual partial pressure of methane on Titan is lower than would be expected over an ocean of liquid methane. This has given rise to the suggestion that oceans on Titan, if any, are mostly of ethane with a 15 to 20 percent lacing of the lighter hydrocarbon. Raoult's Law, $P = XP^0$, where P is the vapor pressure of the solvent over the solution, X is the mole fraction of solvent in the solution, and P^0 is the vapor pressure or pure solvent at the same temperature, would then account for the currently calculated methane pressure.

Harry C. Stubbs
("Hal Clement")
Milton, MA

The Artist Replies

Sir / In your March '84 issue, you published a letter by D.M. Graham critiquing my article and painting about Titan in "A New Mission to Saturn" (ASTRONOMY, December 1983). He was absolutely right — for 50% of his letter!

It is true that frozen methane is denser than its liquid counterpart, a fact I overlooked while researching my painting of Titan. With regard to the floes on the surface, however, several models were being explored by the scientific community at the time. These models included methane mixed with other ices, including water. Several of these models would allow glacier-like floes on the surface.

Between the time the article was written and the time it was published, Titan went through three major transformations in the minds of researchers here on Earth. After establishing that there was not enough methane "precipitation" near the surface to support the idea of a liquid methane ocean, they decided that a mix of liquid methane and nitrogen or ethane might fit the bill. Later it was suggested that there was no liquid on Titan's surface at all, leaving a landscape similar to the surface of Ganymede. It is currently thought that Titan is completely covered by an ocean of ethane, mixed with acetylene sludge.

Science changes so quickly that it is hard to keep up with models of various worlds, especially one like Titan, which is being scrutinized at furious rates. I find letters like Mr. Graham's very important — any input is appreciated!

Michael W. Carroll
San Diego, CA

Behind the Scenes | Space in the News

America's national space agency has specialized in pulling off truly remarkable feats. To me, the most impressive will always be the first probes to Mars, Venus, Mercury, Jupiter, and Saturn — missions of pure adventure to worlds unseen — and the first steps toward exploring the Moon.

More recently, despite its budget and schedule problems, the Shuttle, America's "space truck," has made near-Earth orbit operations routine. Routine? Yes, but sublime nonetheless. Those photos of astronaut Bruce McCandless floating free above our planet left me speechless, as I imagined myself floating there in space beside him.

The next logical step, the permanently manned space station mandated by the President in his State of the Union Address, apparently took a lot of people by surprise, including NASA, the aerospace firms that will build the station, and ASTRONOMY. We went rummaging through all the NASA documents and press release material in our library to see what we had on NASA's space station plans — and came up empty-handed. A few phone calls later, we knew the NASA public information folks hadn't been expecting a presidential mandate for a space station either! They had been waiting for the Fourth of July.

So we've had to work quickly to bring you this month's lead — the biggest news right now is that there isn't much to report on what the station will actually be like and what it will do — but we promise to bring you more news and information as plans develop.

In our second lead, author Linda Strand poses some difficult questions about planetary exploration. "How much," she asks, "do we really know about the conditions on other worlds? What chances should we take in exploring them? Should we keep them pristine for the sake of future research?" These are tough questions; I don't pretend to have the answers.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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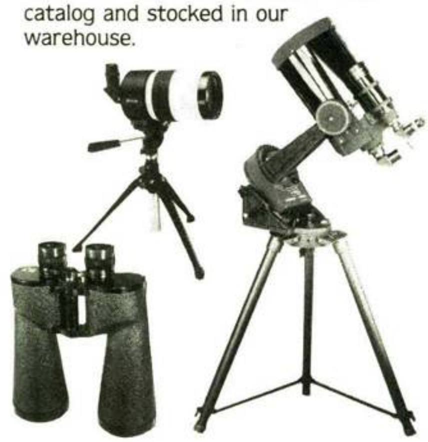

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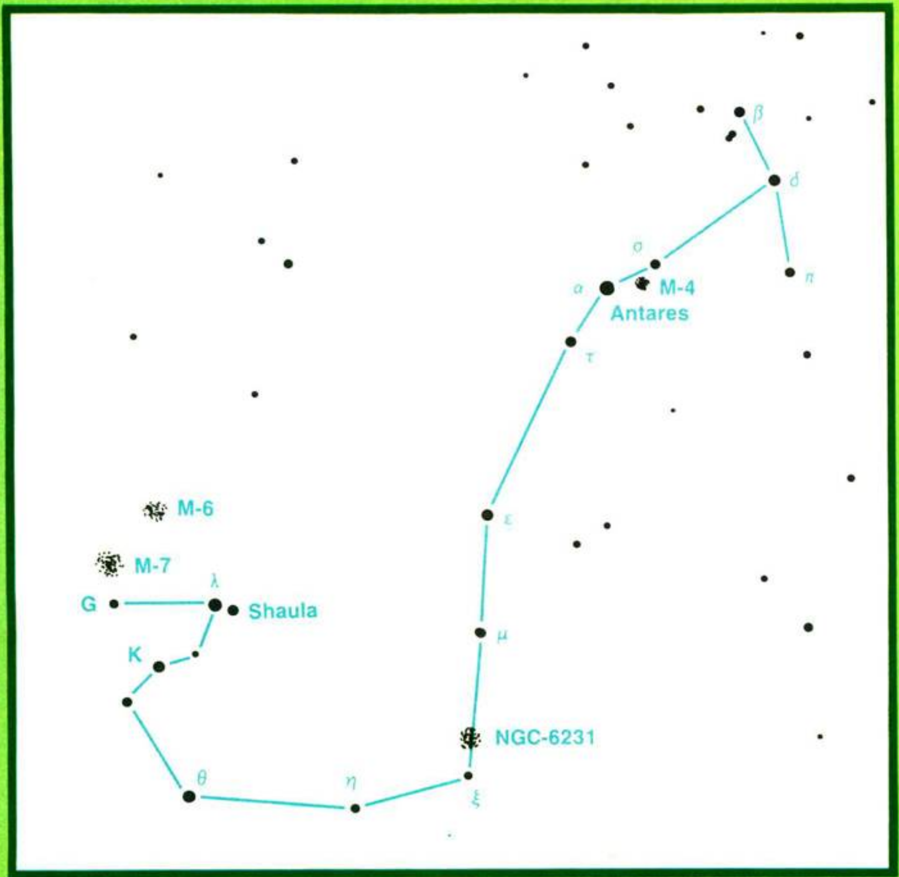
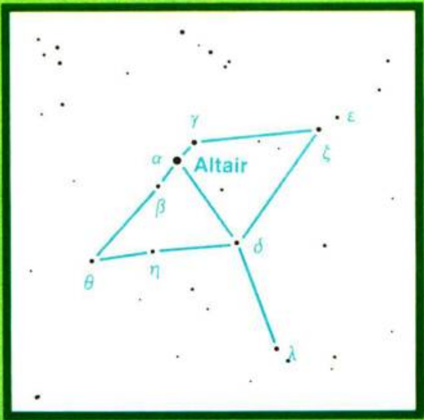
Viewing the Summer Constellations

Gazer's Gazette

by
Earle F. Dodds



Above: Antares, Shaula, and other stars in Scorpius' twisted frame mark the coming of summer constellations. The Scorpion holds many bright open star clusters, the best of which are M-6, M-7, and NGC-6231. M-4, a bright globular cluster, lies near Antares. Right: Dominated by Altair, Aquila the Eagle takes the form of a broad V with extensions.

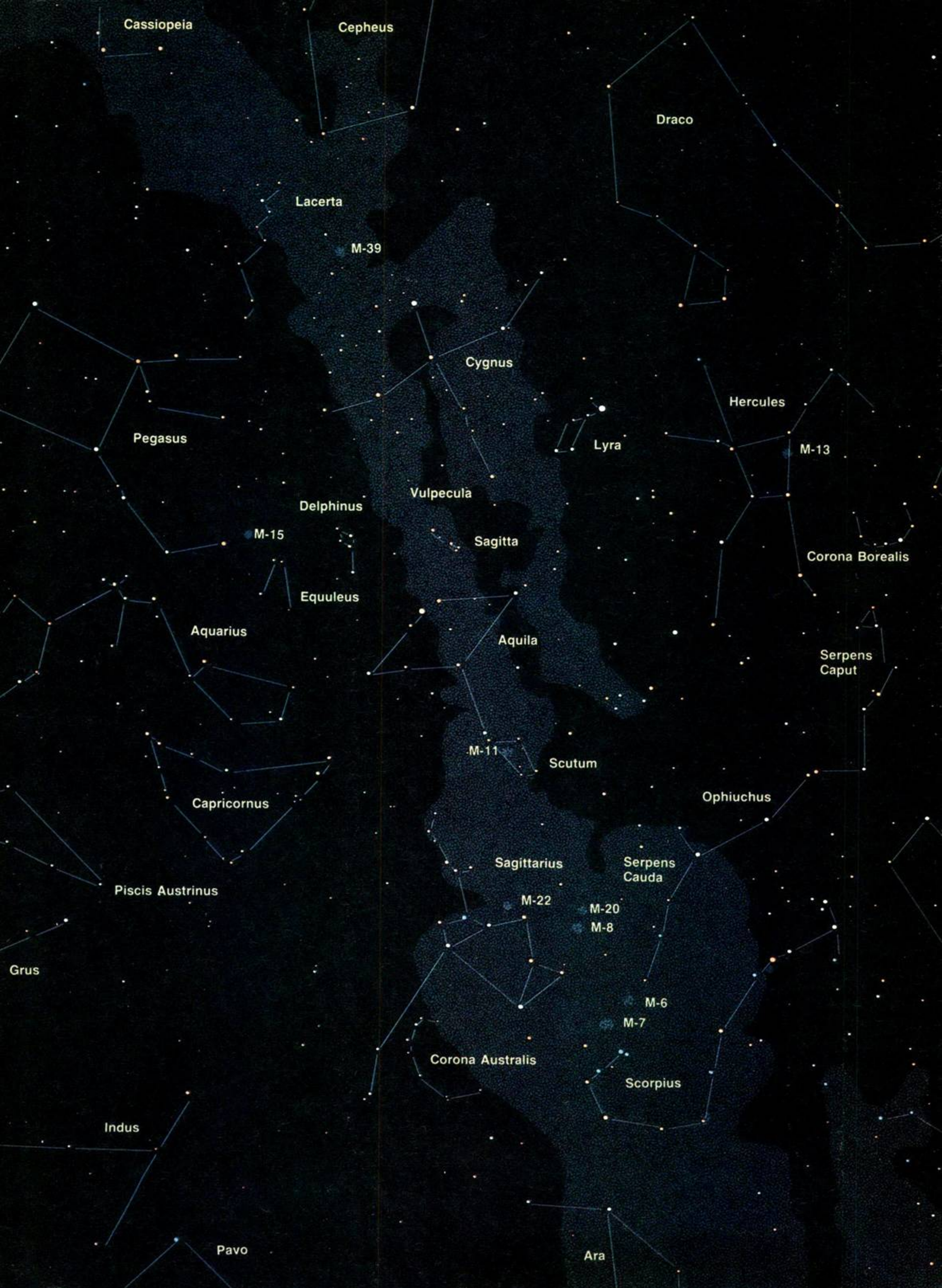


The first two parts of this series — which ran in December 1983 and March 1984 — explored the constellations and binocular showpieces of the winter and spring skies. Now it is time to look skyward to the summer stars and constellations, which hold new treasures for patient observers.

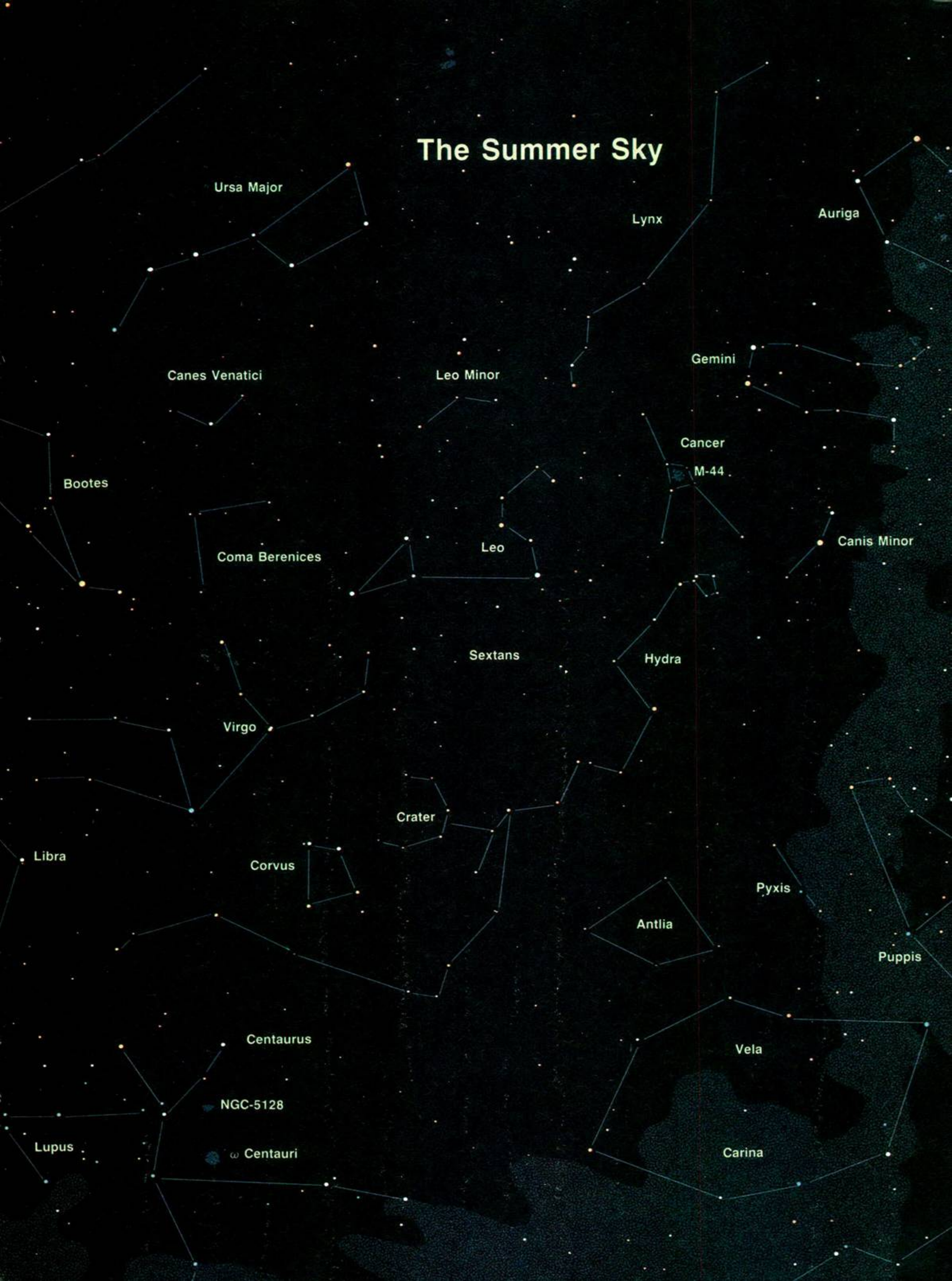
On June 1, at 10:00 p.m., the spring stars are still shining, and you can even catch remnants of the late winter sky — Auriga's golden beacon, Capella, sinking into the horizon, and the Twins Castor and Pollux slipping toward the west. Springtime's Realm of the Galaxies still looms large, and an eerie irregular glow begins to rise in the east. This glow is the summer Milky Way, the combined luminescence of millions of our Galaxy's stars. Indeed, as we look toward its densest region, we look toward the very center of our home star system.

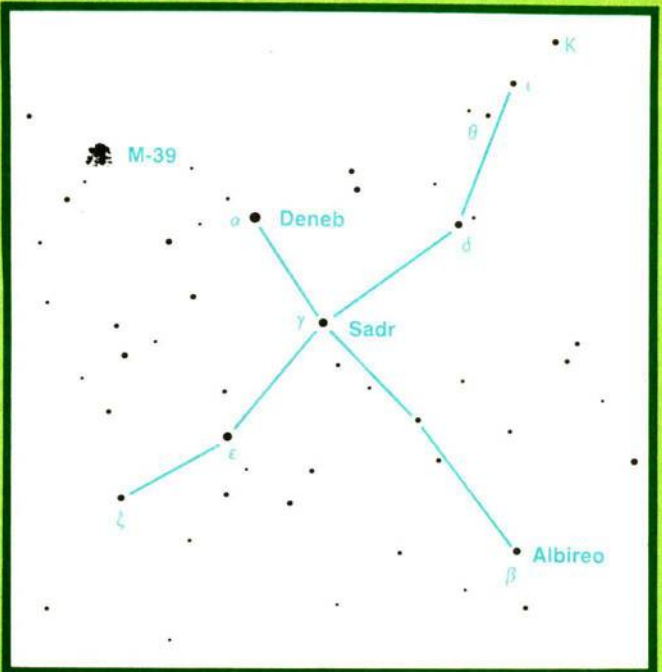
Though it is primarily a spring figure, the dominant feature of the northern sky is the Big Dipper, the prominent asterism that forms the center of Ursa Major, the Great Bear. All eight stars in the Dipper appear to be traveling together through space. The "bowl stars'" are Dubhe (Alpha [α] UMa), Merak (Beta [β] UMa), Phecda (Gamma [γ] UMa), and Megrez (Delta [δ] UMa). The other four stars form the dipper's handle: Alioth (Epsilon [ε] UMa), Mizar (Zeta [ζ UMa), Alcor (80 UMa), and Alkaid (Eta [η] UMa). As the middle star in the handle, Mizar and Alcor form a challenging naked-eye double star; if you see two stars, your eyesight is sharp.

South of Ursa Major lies Leo the Lion, a group of stars that appears like a backward question mark, or sickle, followed by a bright triangle of stars. The sickle represents the lion's head and mane, while the triangle — which contains the blue-white star Denebola (Beta [β] Leo) — forms his hindquarters. The most striking star in the area is Regulus (Alpha [α] Leo), the base of the sickle. East of Regulus are two bright stars, one yellowish, the other dazzling blue-white. They are Arcturus, the brightest star


Cassiopeia
Cepheus
Draco
Lacerta
M-39
Cygnus
Hercules
Pegasus
Lyra
M-13
Vulpecula
Delphinus
M-15
Sagitta
Corona Borealis
Equuleus
Aquarius
Aquila
Serpens
Caput
M-11
Scutum
Capricornus
Ophiuchus
Sagittarius
Serpens
Cauda
Piscis Austrinus
M-22
M-20
M-8
Grus
M-6
M-7
Corona Australis
Scorpius
Indus
Pavo
Ara

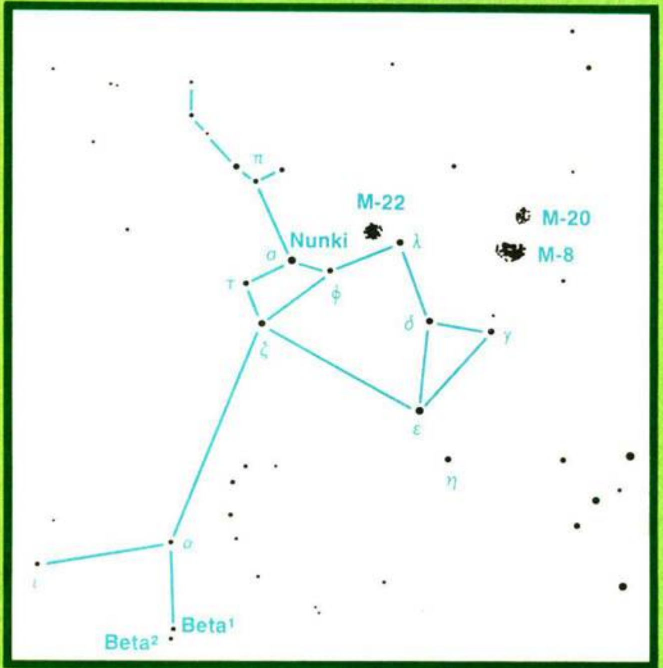
The Summer Sky


Ursa Major
Lynx
Auriga
Canes Venatici
Leo Minor
Gemini
Bootes
Cancer
M-44
Coma Berenices
Leo
Canis Minor
Sextans
Hydra
Virgo
Crater
Libra
Corvus
Pyxis
Antlia
Puppis
Centaurus
Vela
NGC-5128
Lupus
ω Centauri
Carina



Cygnus the Swan represents the richest area in the northern Milky Way; bright stars Deneb and Albireo mark the Swan's tail and head, respectively. Groups of stars and elusive nebulae fill the region — use binoculars to scan around. The large binocular cluster M-39 lies 10° east and a little north of Deneb.

Looking toward Sagittarius the Archer, we peer at the richest conglomeration of stars, gas, and dust in our Galaxy — the direction of the Galactic center. The constellation's form is like a teapot, rather than an archer. The bright nebulae M-8 and M-20 and the globular cluster M-22 all lie within Sagittarius.



in Bootes the Herdsman, and Spica, Virgo the Virgin's primary beacon. Along with Regulus, these stars flank the Realm of the Galaxies — the region holding the densest concentrations of galaxies in the sky. You'll need a telescope to see them, however, since most are remote and faint. An easy method of finding Arcturus is to follow the Big Dipper's handle, which "arcs to Arcturus." You only need continue the arc to stumble upon Spica.

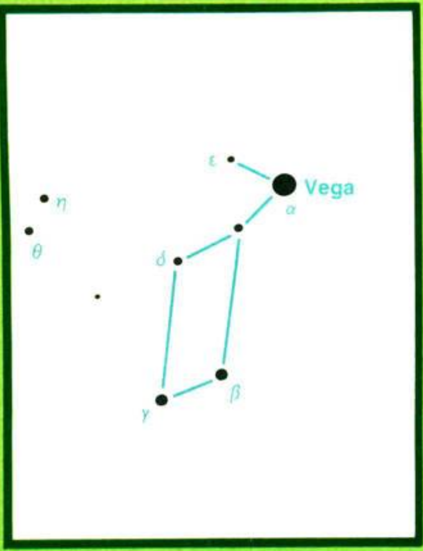
Less conspicuous groups of stars fill in around the bright evening stars. Corona Borealis, the Northern Crown, is a compact little string of faint naked-eye stars on the eastern side of Bootes. It contains Alphecca, a second-magnitude star that is slightly variable in luminosity. On the other side of Bootes is Coma Berenices, Berenice's Hair, which is principally composed of a large naked-eye star cluster called Melotte 111. (Many galaxies occupy this area, too, but you need a telescope to observe them.) This cluster appears as a large hazy patch of light showing a few stars — a slightly better sight than the Beehive cluster in Cancer, which is now setting in the west. Just north of Coma Berenices lies Canes Venatici, the Hunting Dogs, which also contains many faint galaxies. Its brightest star is a third-magnitude sun called Cor Caroli, or "Charles's Heart." The astronomer Edmond Halley named it for Charles II of England.

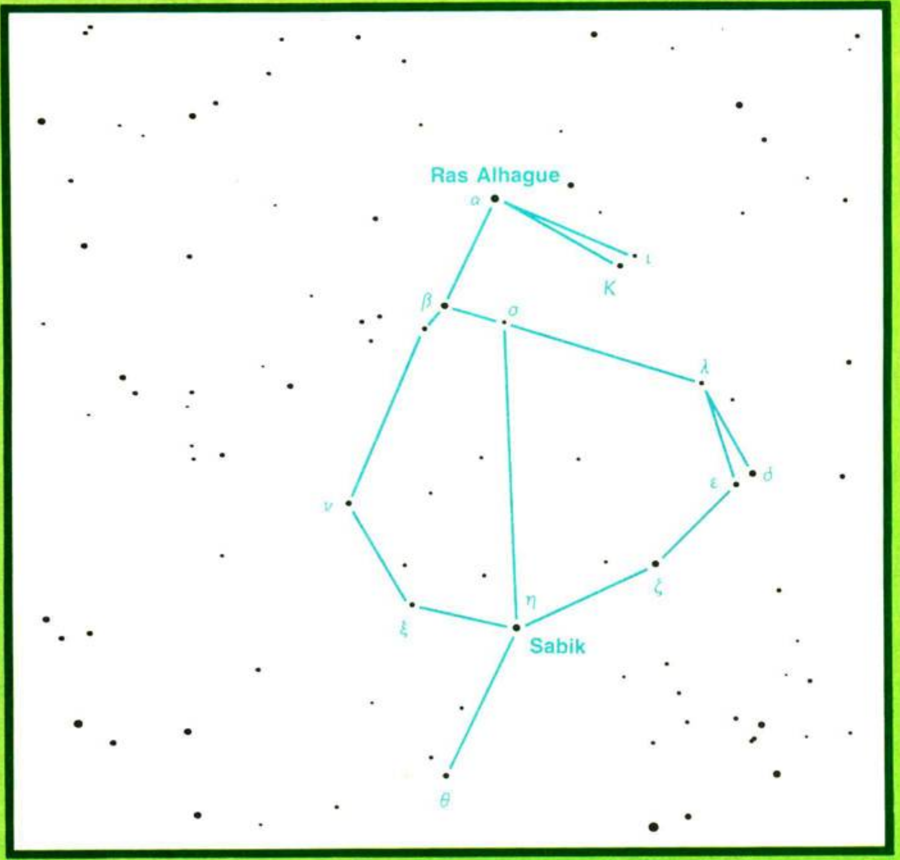
Hercules the Strongman marks the coming of the brilliant summer Milky Way, which is rich in bright stars, nebulae, and star clusters. Hercules itself contains one of the finest globular clusters, M-13, visible in binoculars as a small nebulous ball of light. As you gaze at it, remember that you're looking at the combined light of half a million stars. Hercules' brightest star is Ras Algethi, which means "the kneeler's head." At third magnitude, it is visible but not terrifically bright to the naked eye.

South of Hercules is the giant box-shaped constellation Ophiuchus the Serpent-Bearer. Ophiuchus is home to several bright stars, the most noteworthy being Ras Alhague (Alpha [α] Oph), the "head of the serpent charmer." It glows at magnitude 2 and has a whitish color. Other bright stars are Cebalrai (Beta [β] Oph), a third-magnitude star, and Sabik (Eta [η] Oph), a telescopic double star of magnitude 2.4. Straddling Ophiuchus to the east and west are the two components of Serpens the Serpent. To the west, Serpens Caput (the serpent's head) snakes its way north of Libra and almost reaches up to Hercules. In the east, Serpens Cauda (the serpent's tail) is buried amidst the rich summer Milky Way just north of Scorpius; it contains intriguing binocular fields for casual scanning.

By late evening, the brilliant first-magnitude gleam of Antares (Alpha [α] Sco) pulls above the horizon, signaling the arrival of the first major summer constellation — Scorpius the Scorpion. This is a grand arrangement of bright, captivating stars that dazzles naked-eye and binocular viewers. Antares itself is one of the most obviously colored stars, a blazing deep orange. (Antares means "rival of Mars.") With a telescope, you may discover that it is slightly variable in brightness, and that it harbors a tiny greenish companion. Adjacent to Antares is the bright, loose globular star cluster M-4; at magnitude 6, it is just within the naked-eye limit under good skies, appearing as a tiny fuzzy "star." Northwest, in the Scorpion's head, lies Acrab (Beta [β] Sco), a telescopic triple star, which otherwise appears as an ordinary blue-white third-magnitude star. At the other end of the constellation is Shaula (Lambda [λ] Sco), which marks the creature's stinger. This star glows at magnitude 1.6 and is blue-white in hue. Two large scattered open star clusters lie relatively near Shaula and the Scorpion's tail — M-6 and M-7. M-7 shines at fifth magnitude and spans an entire degree, making it an easy naked-eye object. With binoculars it breaks up into multitudes of tiny stellar pinpoints — a splendid sight! At magnitude 6 and half a degree in diameter, M-6 is slightly smaller and dimmer. It is nevertheless visible to unaided eyes from relatively dark locations. Turning your binoculars toward it will show a strange pattern of stars — some observers call it the Butterfly cluster — with a bright orange star embedded near the center. Another bright cluster, NGC-6231, lies in the southwest portion of the Scorpion's body.

Northeast of Scorpius is the bright, unmistakable "teapot" shape formed by the eight principal stars of Sagittarius the Archer. This constellation lies right in the thick of the summer Milky Way, and





Above: Though small, Lyra the Lyre contains the fifth brightest star in the sky, Vega. Most of the stars in this small grouping are young, blue-white ones, like the double-double (Epsilon [ε] Lyr). Right: Ophiuchus the Serpent-Bearer, surrounded to the north and south by a serpent, contains many globular clusters, but is not terribly impressive to the naked eye.

contains the point dubbed 0° galactic longitude on the galactic equator — the direction of our Galaxy's center. Quite logically, this is one of the richest areas of sky, containing many bright stars, clusters, and nebulae. The brightest star in the group is Nunki (Sigma [σ] Sgr), a blue-white star of second magnitude, which marks part of the teapot's handle or the Archer's tensed hand. The bow — or teapot's spout — is marked by Kaus Media (Delta [δ] Sgr), Al Nasl (Gamma [γ] Sgr), and Kaus Australis (Epsilon [ε] Sgr). They are second and third-magnitude stars of little interest, but they provide a starting point for finding several nebulae. A few degrees north of Al Nasl lies a large fuzzy naked-eye patch of misty light — M-8, the Lagoon Nebula. Training binoculars on this object will show a degree-wide haze involved with a bright, compact star cluster. This is one of the finest emission nebulae in the sky, a prime example of a region where new stars are being created. Just north of M-8 is a slightly smaller patch of nebulosity — not easily visible without binoculars — called M-20, the Trifid Nebula. A telescope shows three dark lanes trisecting this nebulosity, hence its nickname. Binoculars show a faint double patch of grey light. The star Lambda (λ) Sgr marks the teapot's lid; near it is a large globular cluster, M-22, which nearly rivals M-13 in Hercules.

Following the band of Milky Way northward, we find the bright constellation Aquila the Eagle and the diminutive Scutum the Shield. Aquila is basically V-shaped, with extensions that form the tail and a wing of the Eagle. The brightest star is Altair (Alpha [α] Aql), a first-magnitude blue-white star that constitutes one third of the Summer Triangle — an asterism that also includes Deneb in Cygnus and Vega in Lyra.

Helping to form the V shape in Aquila are Denebokab (Delta [δ] Aql), the "tail of the Eagle," Tarazed (Gamma [γ] Aql), and Theta (θ) Aql; all three are third-magnitude stars. Nestled under the Eagle is the little constellation Scutum, whose location appears as a bright patch in the Milky Way. This is the so-called Scutum Starcloud, a vast conglomeration of hundreds of thousands of stars. The constellation Scutum itself is small and rather inconspicuous, appearing as a box-shaped group of fourth and fifth-magnitude stars. A fine open cluster, M-11, lies in Scutum. It is a rich grouping of hundreds of stars and is often called the Wild Duck Cluster; a look at it with binoculars will show you why.

One of the brightest and most easily recognizable constellations is Cygnus the Swan, principally composed of the asterism known as the "Northern Cross." Included in it are Deneb, which shines at magnitude 1.3 and marks the head of the cross, Albireo (Beta [β] Cyg), a beautiful binocular double star at the base of the cross, Sadr (Gamma [γ] Cyg) in the center, and Gienah (Epsilon [ε] Cyg) and Delta (δ) Cyg at opposite ends. Interpreting Cygnus as a Swan, Albireo is the head, Deneb the tail, and Gienah and Delta Cyg the wings. The area is riddled with bright stars, most of which are young blue and white stars; it makes for enjoyable binocular scanning. One of the biggest and best open clusters for binocular observers is M-39 in northern Cygnus, a triangular assemblage of 25 stars of seventh magnitude and fainter.

Pocketed between Cygnus and Hercules is the small, bright group of stars known as Lyra the Lyre. Vega (Alpha [α] Lyr) is a blue-white zero-magnitude star that dominates the little constellation; its great brilliance is highlighted by the fact that Vega passes directly overhead as viewed from locations near 40° north latitude. Beta (β) Lyrae, which shines at about fourth magnitude, is an eclipsing binary star — every 13 days it varies by one magnitude, from 3.4 to 4.4. Binoculars will allow you to monitor its regular variation. Epsilon (ε) Lyrae is a well-known quadruple star called the "double-double." It consists of two stars — one fourth magnitude and one fifth magnitude — each of which, in turn, is a double. Binoculars will show you the primary pair, but you'll need a telescope to separate all four stars.

Early morning brings new stars, ones that show themselves best during the evening hours of autumn. The Great Square of Pegasus, arcing strings of stars composing Andromeda, the giant W of Cassiopeia — all hold their own attractive sights. But having spent an evening inspecting the summer stars, you're probably getting a bit sleepy, so take one last look at the cross of Cygnus and the eerie glow of the Milky Way. After all, the stars will be there again tomorrow night!

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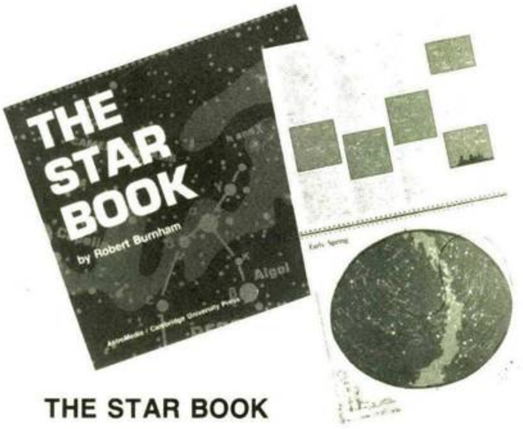
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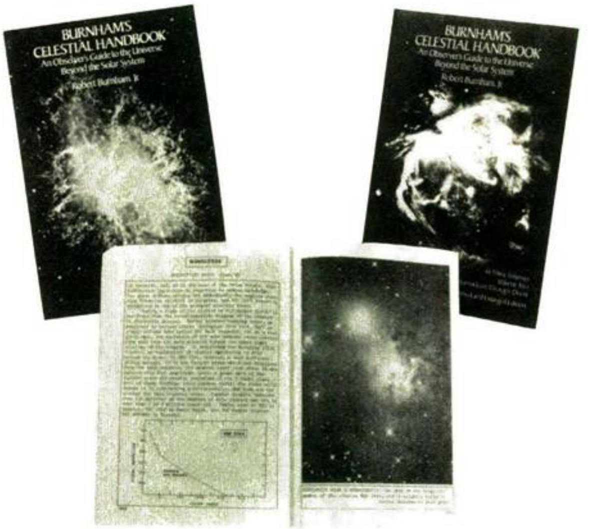
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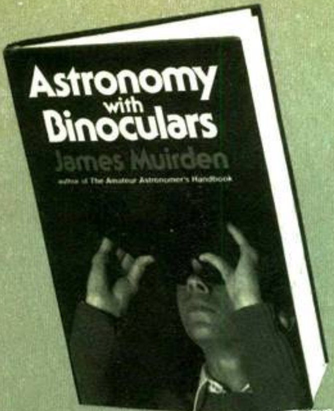
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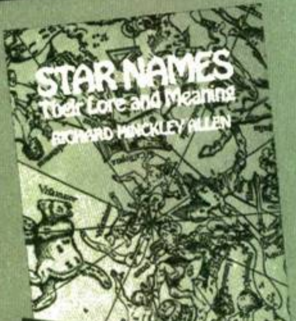
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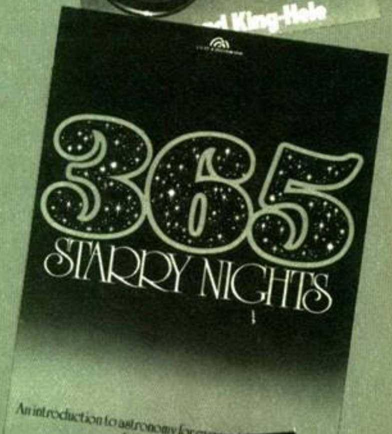
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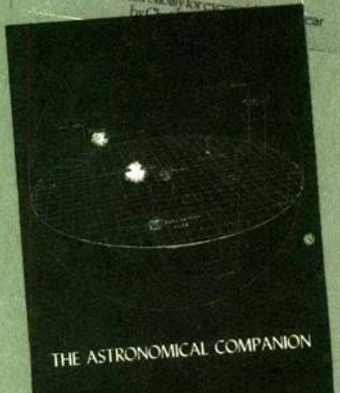
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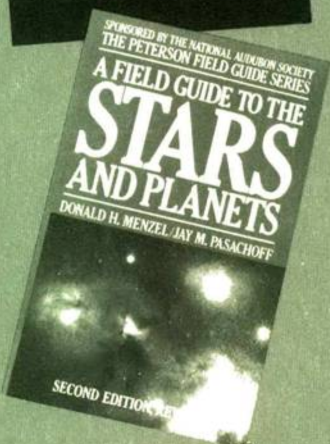
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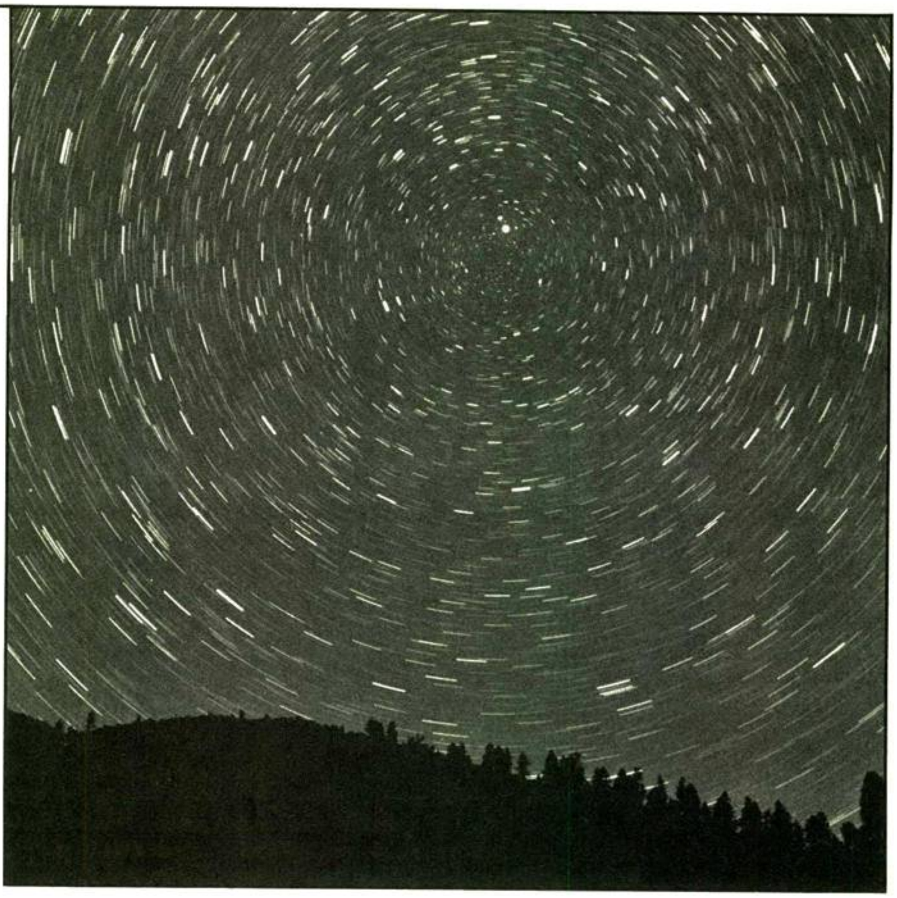
Eye on the Sky

A Month of Oppositions

by Fred Schaaf



Polaris shows a slight trail in this 15-minute exposure — proof that it doesn't quite mark the north celestial pole. Karl Keranen used ASA 400 film and a 50mm lens at f/2.8 for this photo.

Gleaming against the stars of Scorpius, the brilliant planet Venus seems suspended above the manmade glare of San Francisco in this photo by Jim Baumgardt.

The Wanderers

June is a month of almosts. We almost get a lunar eclipse; Mars and Saturn almost have a conjunction. There are problems for observers — both Venus and Mercury are poorly positioned for viewing, the outer planets occupy the southernmost portion of the zodiac, and observers at mid-northern latitudes face the shortest nights of the year. Despite these seeming limitations, however, June turns out to be one of the best months for astronomy. Why? Because three planets are at opposition and two more are nearly at their best. Furthermore, that near-conjunction of Mars and Saturn is a very fine pairing of the two bright worlds.

The apparent motions of **Mars** and **Saturn** through the sky will be interesting to watch. The month begins with Mars still in hot pursuit of Saturn as both continue to retrograde in Libra after their early May oppositions. Mars, however, halts its retrograde motion on June 20, over three weeks before Saturn — and before Mars can catch the latter for a conjunction. As a matter of fact, Mars moves slower than Saturn by the 12th, when the Red Planet lies just east of Saturn in right ascension. Despite their slight difference in right ascension on June 11, Mars and Saturn are no closer than 4.3°, since Mars is south of the ecliptic and Saturn well north of it.

Mars and Saturn were much closer during their conjunction in February, but both planets are brighter now — especially Mars. Mars begins June brighter than magnitude −1.5 and therefore about two full magnitudes brighter than Saturn. During June, Saturn loses only a bit of its luster, while Mars fades by over half a magnitude — though still brighter than any of the spring or summer stars. As in February, the planetary duo is near Alpha (*α*) Librae. Mars traces a fish-hook path through the sky in June after starting a few degrees southwest of the star. On June 9, two nights before the near-conjunction, the Moon passes between Mars and Saturn as seen from Europe and northern Asia.

June, however, is the best month for observing Uranus, Neptune, and Jupiter. This year, **Uranus** reaches opposition on June 1, but just a few days later the waxing Moon begins to interfere. Viewers with dark skies should wait out the Moon and try to see fifth-magnitude Uranus, lying about 5½° northeast of Antares. By late June this blue-green gas giant has moved more than a degree (retrograde) and lies just over a degree southeast of Omega (ω) Ophiuchi. Uranus will have only one more opposition before the Voyager 2 spacecraft races past it in January 1986 — by which time naked-eye observers will be watching Comet Halley. Southern peoples get an occultation of Uranus on the 12th, as well as the best shot at seeing the penumbral eclipse of the Moon on the 12th/13th.

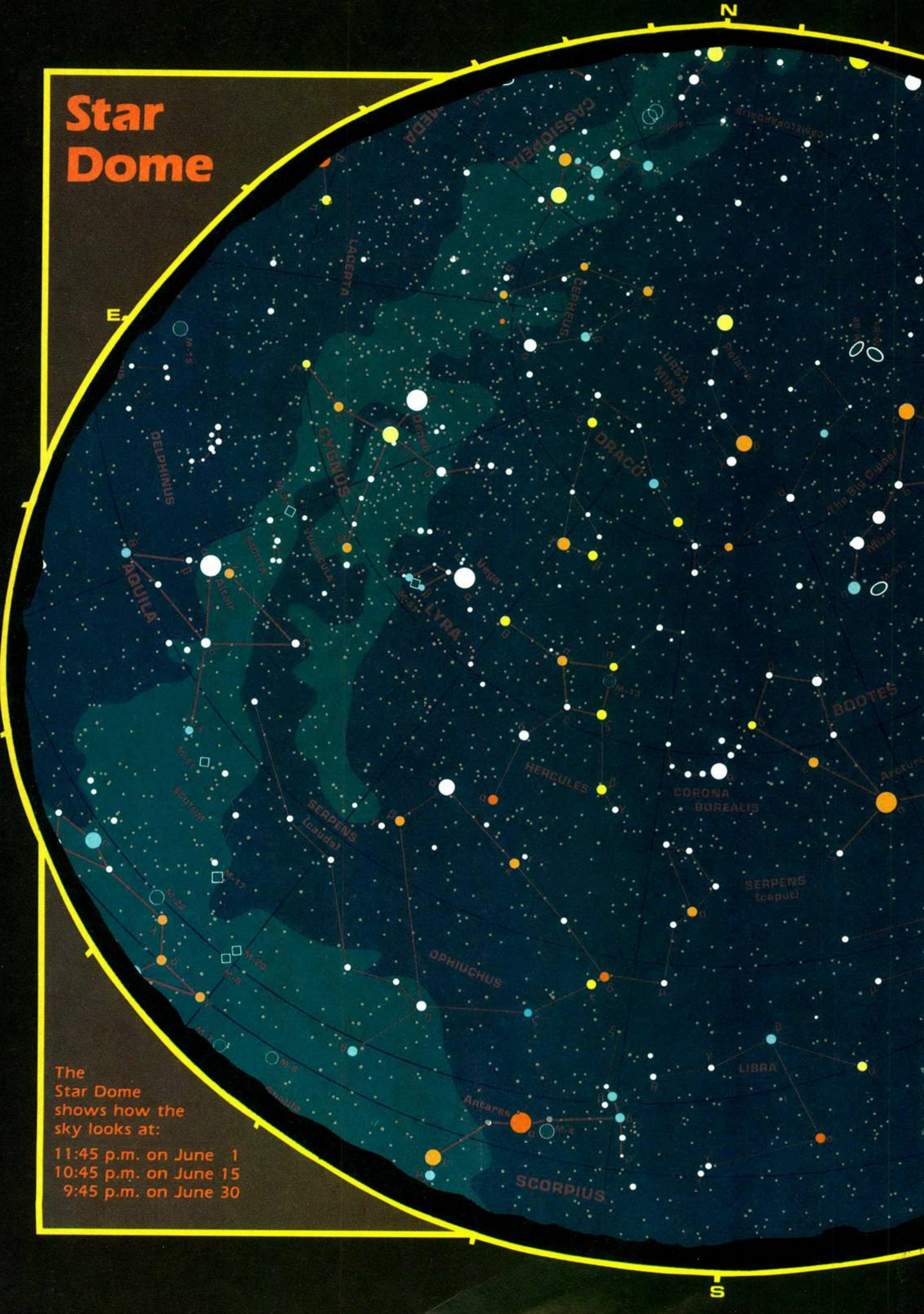
But we need not envy Australians their view of this eclipse — even the best shot is not good enough. The Moon skims only the outer edge of the Earth's penumbra and the shadow is not dark enough to detect on the Moon's north limb.

Although Neptune and Uranus are about the same size, the former is 29 AU from the Sun — 10 AU farther than Uranus. (One AU equals the average distance between Earth and Sun.) Thus, **Neptune** appears much smaller and fainter than its sister world. You'll need a detailed star chart (see page 83 of the January issue) and good binoculars to find Neptune, now very near the open star cluster M-21 and less than one degree north of the Trifid Nebula (M-20). As the month opens, this distant world is moving westward — that is, retrograde — from almost exactly on the galactic equator in star-clouded Sagittarius.

These dim, distant gas giants are far less impressive than their big brother **Jupiter**. This mighty world is an imposing sight at magnitude −2.6 as it retrogrades to just north of the Teapot's peak in Sagittarius. There, on June 29, Jupiter reaches opposition. This is the giant planet's most southerly opposition for the northern

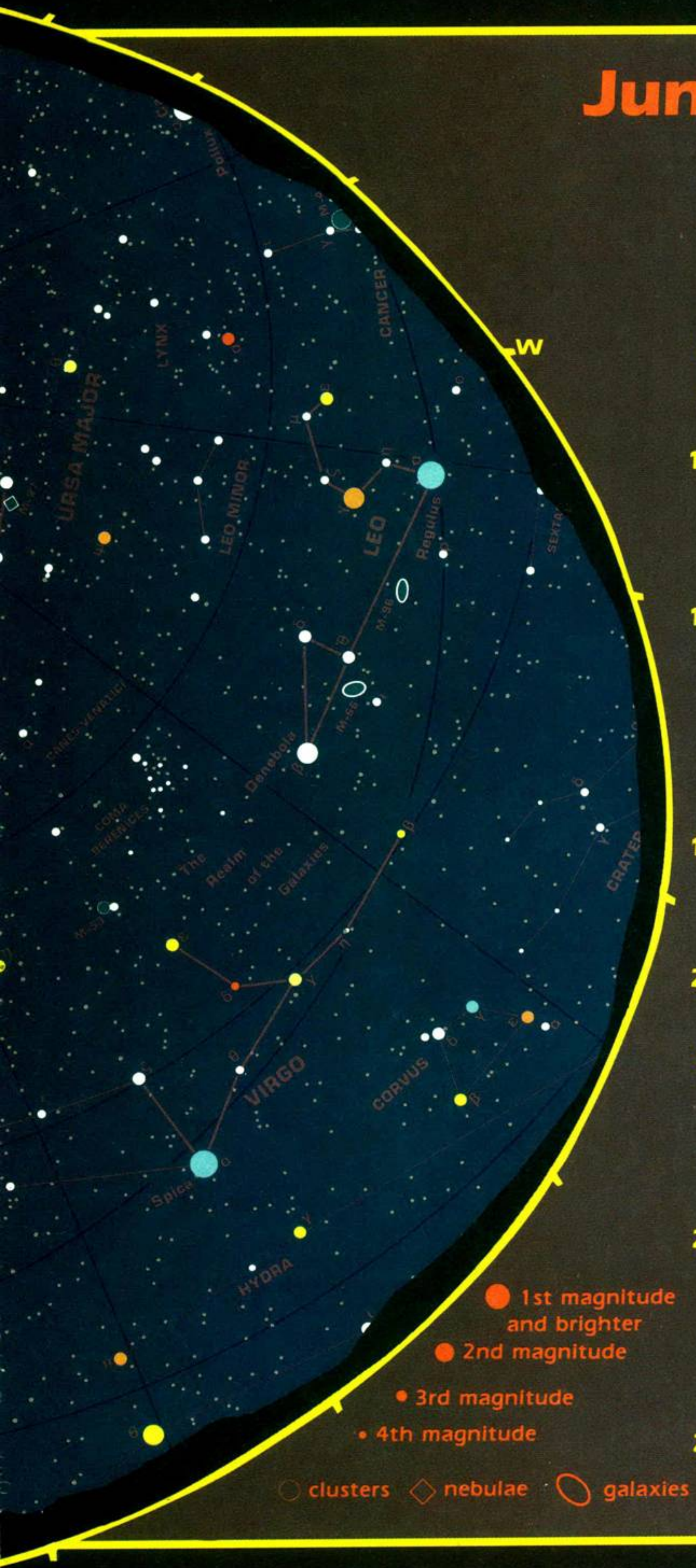
For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Star Dome


N
E
S
CASSIOPEIA
MEDA
CAMELOPARDALIS
LACERTA
CEPHEUS
URSA MINOR
Polaris
DRACO
The Big Dipper
Mizar
M-81
M-82
M-51
CYGNUS
Deneb
DELPHINUS
M-15
AQUILA
Altair
Sagitta
Vulpecula
M-27
M-57
Vega
LYRA
HERCULES
M-13
BOOTES
Arcturus
CORONA BOREALIS
SERPENS (cauda)
SERPENS (caput)
OPHIUCHUS
SCUTUM
M-11
M-17
M-22
M-20
M-8
M-7
M-6
Shaula
Antares
M-4
SCORPIUS
LIBRA

The Star Dome shows how the sky looks at:

11:45 p.m. on June 1
10:45 p.m. on June 15
9:45 p.m. on June 30


Pollux
LYNX
CANCER
URSA MAJOR
LEO MINOR
LEO
Regulus
SEXTANS
M-96
M-66
Denebola
CANES VENATICI
COMA BERENICES
The Realm of the Galaxies
CRATER
M-53
VIRGO
CORVUS
Spica
HYDRA
W
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

June Sky Almanac

1st Uranus is at opposition in the constellation Ophiuchus — see Gazer's Gazette, page 52.

6th First Quarter Moon happens at 12:41 p.m. EDT.

7th The Moon is at perigee at 7:24 a.m. EDT: 229,639 miles.

13th The Moon is Full at 10:42 a.m. EDT; there is also a penumbral lunar eclipse, but it occurs over the eastern hemisphere and will be undetectably slight.

14th Around 2:30 a.m. local daylight time, the summer Milky Way is at its best. The Summer Triangle of Vega, Altair, and Deneb is high overhead, and the glorious regions in Scutum and Sagittarius are gliding above the southern horizon.

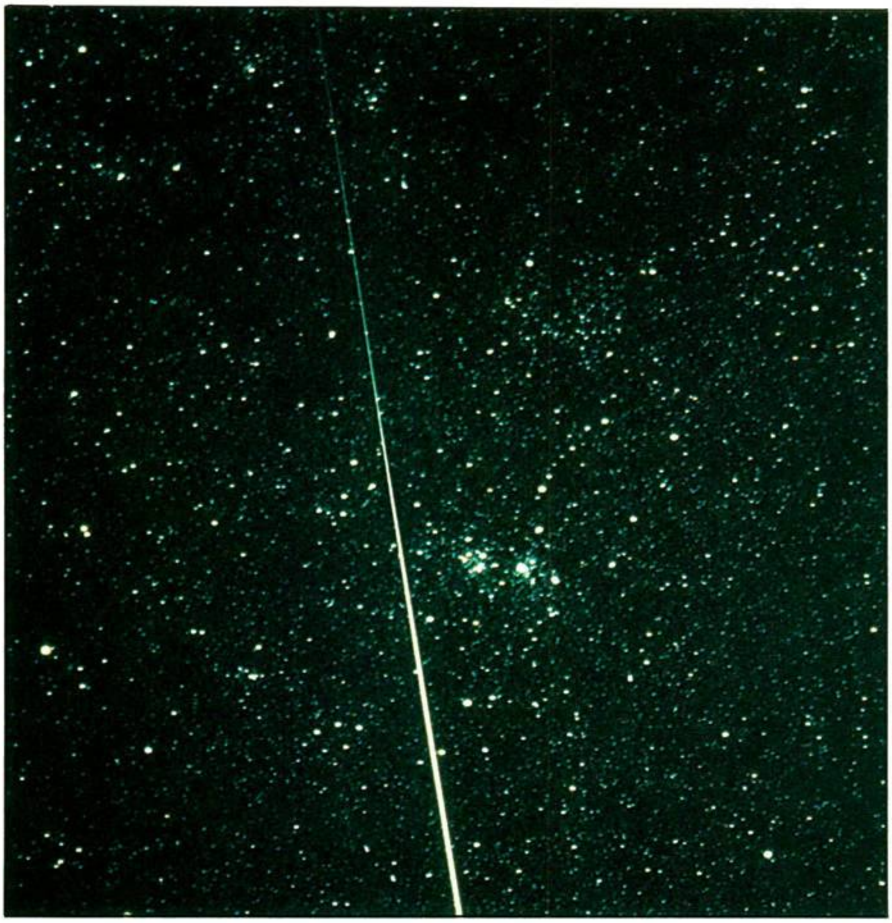
15th Venus passes superior conjunction with the Sun. Start looking for it low in the western sky after sunset about six weeks from now.

20th Mercury is at perihelion, and the Moon is at apogee at 3:44 p.m. EDT: 251,178 miles.

21st Summer begins at 1:02 a.m. EDT, when the solstice occurs. An hour later, Neptune is at opposition in the constellation Sagittarius. Finally, at 7:10 a.m. EDT, the Moon reaches Last Quarter.

23rd Mercury passes through superior conjunction with the Sun, on its way to an unfavorable elongation in the evening sky in July and August. You'll see it most clearly in the morning sky in the middle of September.

28th The Moon is New at 11:18 p.m. EDT. Later in the day, Jupiter reaches opposition.



Richard Andreassen caught a bright meteor in his shot of the Perseus Double Cluster (h and χ Persei). Although the clusters appear together, h Persei (right) is closer to us by 1100 light-years.

hemisphere. Aside from revealing its four bright Galilean moons, 20x binoculars will just show the planet's 47 second-of-arc disk.

By midnight, all the outer planets are visible in the south. But what of the inner planets?

On the opposite side of the zodiac, **Venus** and **Mercury** reach superior conjunction just eight days apart this month, and both are absent from the northern sky all month. Right now, Venus can't be seen from anywhere on Earth. As a matter of fact, when Venus comes to superior conjunction on June 15, it is only five days past the ascending node of its orbit, when it crosses the ecliptic moving northward. So Venus actually passes directly behind the disk of the Sun as seen from Earth.

Mercury reaches perihelion on June 20. Lying just 0.31 AU from the Sun, this is the planet's closest perihelion of the decade — in fact, Mercury gets no closer to the Sun this century. This occurs little more than a month after Mercury came to its most extreme aphelion of the decade, nearly 0.47 AU, on May 7. And there is yet another record extreme this month: Venus reaches its greatest distance from us for the decade on June 15, 1984. Its disk will then be just 9.6 arc-seconds across.

The Starry Sky

This is a good month to take special note of the stars' most subtle features — color. Some people are skeptical (and/or not very interested) about the colors of stars. True, these tints are hardly overwhelming, but they do exist, and unaided eyes can detect them.

One way to rate stars is by creating an arbitrary scale. For example, you might use 0 for "very blue," 3 for "white," 5 for "yellow," 7 for "orange," and 10 for "deep red." You'd never use the extreme ends of this scale; even 1 or 9 might be used only for those spectacular hues resulting from the contrast between double stars seen through a telescope; the June sky offers many fine examples. But if we confine ourselves to naked-eye and binocular observations, what do we find?

The Star Dome colors are "coded" indicators of what you actually see — though the true hues are not as intense. Of all the first-magnitude stars now visible, only one tends strongly toward deep orange — **Antares**, the heart of **Scorpius** the Scorpion, prominent in the southeast. (Antares means "Rival of Mars.") This star is a red giant, a huge elderly star whose vastly distended outer layers are almost as tenuous as a good laboratory vacuum. Orion's Betelgeuse is usually a bit brighter, bigger, and perhaps a bit ruddier than Antares.

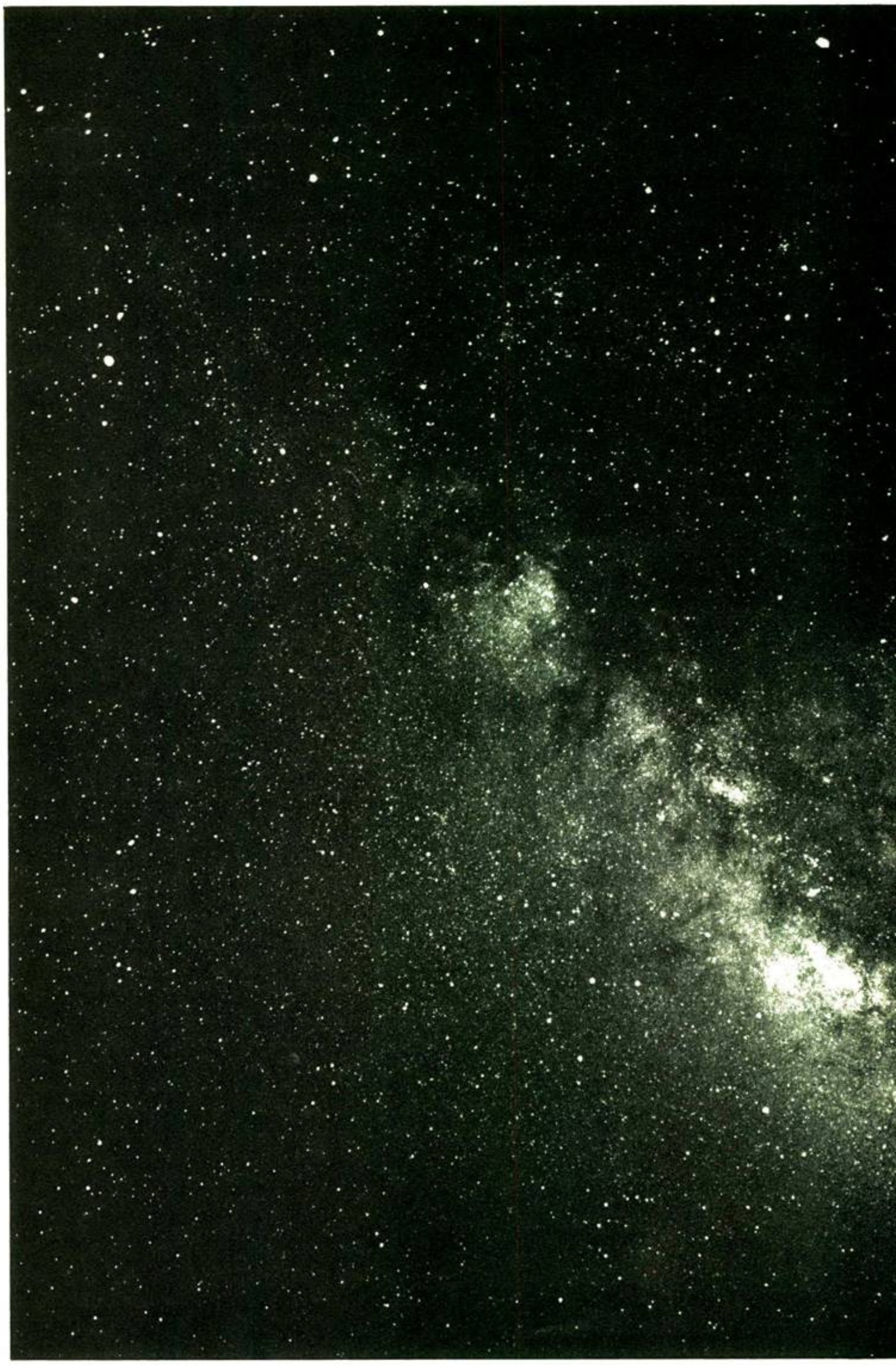
Light-orange stars seem to be more common. Not far from Antares is one example — **Epsilon** (ε) **Scorpii**, but it may represent the faintest a star can be for its color to register on the photoreceptor cells in our eyes. A better example now lies high in the west — familiar **Arcturus**. Another prominent orange star in the June sky is second-magnitude **Kochab**, the brightest star in the bowl of the Little Dipper (officially the constellation **Ursa Minor**, the Small Bear). This, of course, is the constellation that bears **Polaris**, the North Star. June evenings are distinctly better than other ones for observing the stars in Ursa Minor because they are now well above the pivotal Polaris in the north. And what color is Polaris? A "cooler" color than that of the orange or orange-red stars, the North Star is somewhat yellowish — like our own Sun (which is hotter than the orange stars).

Not far from the Little Dipper hangs the Big Dipper (**Ursa Major**, the Great Bear), dangling from the end of its handle in the northwest. A few months back we saw that all but the two end stars of the Big Dipper are members of the Ursa Major moving group, stars traveling together through space — and indeed the Star Dome shows that color distinguishes the cluster members from the interlopers in the Dipper pattern. Members are white stars, whereas outsiders **Alpha** (α) **Ursae Majoris** (Dubhe) is orange, and the handle-end, **Eta** (η), is bluish.

Blue and white stars are even hotter than those with a yellow tint, but star color doesn't relate perfectly to temperature — spectral type is the best indicator. A famous mnemonic for the correct order of stellar spectral types, from the hottest to coolest — "Oh, Be A Fine Girl, Kiss Me" — reminds us of the basic spectral types O, B, A, F, G, K, and M. A few other spectral classes are used for special kinds of stars. Star colors on the Star Dome map are really based on spectral class; there are a few cases where this is deceptive in regards to perceived color. Each spectral class is further divided by a scale of numbers ranging from 0 to 9 (in decreasing temperature). Thus the spectrum of an F9 star is slightly different from that of a G0 star. Look for the one star above Antares marked as very blue — on the Star Dome map this is the only prominent type O star now visible. But **Zeta** (ζ) **Ophiuchi** is just an O9 star, scarcely bluer than some of the other stars colored lighter blue (B class) on the map.

Such problems are inevitable with large-scale categorizing. Note **Regulus** of **Leo** the Lion and **Spica** of **Virgo** the Virgin in the western sky — these two do have a slight bluish tint. But the remaining first-

The Milky Way, the plane of our home Galaxy, splits the evening skies of summer. John Sanford's 16-minute exposure captures its glow from Aquila to star-crowded Sagittarius.



magnitude stars — the Summer Triangle of **Vega**, **Altair**, and **Deneb** in the east — are all marked white in Star Dome. Their spectral classes are A0, A2, and A7, respectively, and Vega is bright enough for its slight blue tint to be very noticeable to the unaided eye.

Next month we will further pursue the matter of star colors. In the meantime, try rating these delicate, tricky hues yourself, and compare your findings to our figures next month. While **Libra** the Scales is on the meridian this month, see what you think of the color of **Beta** (β) **Librae** (use binoculars or other optical aid to assist). And, of course, include the bright planets Mars, Saturn, and Jupiter in your color estimates. You'll find that brightness makes a difference.

Skylore

Lupus the Wolf is a fine constellation with three second-magnitude stars, but is too far south for observers in the United States and Europe to see well. Due to precession, though, the constellation appeared higher in the sky in ancient times, and it was known to the Greeks — although not as a wolf.

From early on, the stars of our Lupus were simply an unspecified wild animal that fought with nearby Centaurus the Centaur. The Centaur was often portrayed as clasping the beast in one hand and a wineskin in the other. An apparently modern rendering shows the centaur holding off a rearing wolf with a staff. Lupus appears on Ptolemy's list of 48 constellations, but only as "therion," which means "wild beast."

How did the constellation come to be a wolf? Before the classical period of Greece, these stars may have been the Zibu (Beast) of Euphratean cylinder seals and Urbat, the Akkadian Beast of Death. In Mesopotamia, these stars may have represented Uridimmu, a dreadful lion who served the evil monster, Tiamat.

It is probably only coincidental that the early Arabs called the constellation Al Fahd, Leopard or Panther, and Al Asadah, Lioness, several thousand years later. Apparently, an astrologer's mistranslation of Al Fahd in the Middle Ages gave rise to the idea that the constellation was a wolf. R.H. Allen does mention, however, a claim that the constellation was identified as a wolf as early as 970 A.D. by the Greek lexicographer Suidas. Many hundreds of years later, mythographers proposed that the wolf represented by Lupus was the wolf into which Lycaon was changed when he cut his son up (some say as a meal) to offer to Zeus. This Lycaon, one of the lesser-known characters of that name in Greek myths, was no doubt invoked because very few wolves appeared in the Greek legends.

But the tales of many other cultures have no lack of wolves. The giant wolf Fenris was perhaps the most frightening monster of Norse myth. Even the American Indians viewed the wolf as representative of humanity's maliciousness, as well as (and this is interesting) our restlessness and questioning of fate.

The wolf's reputation is very much undeserved. No person in North America has ever been killed by a wolf, and the animals responsible for the known attacks in Europe were rabid. The intelligence of the animal and its lifelong affection for its mate and kind are qualities we admire. And modern studies verify that wolves have a strong parental instinct, even for the children of other species, including our own. So one of the upbeat legends about these animals — the story of Romulus and Remus being suckled by a she-wolf — has more basis in truth than most of the tales that slander this beautiful wild creature.

ASTRONOMY
Reviews

The Astronomy Disk
Sheridan Simon
5¼" floppy disk, 38-page booklet, $29.95
Prentice-Hall (1984)

One of the biggest problems facing anyone who teaches astronomy is that of *visualization*. Astronomy involves concepts, objects, distances, and time scales that lie far outside the experience of most students. As a result, educators have evolved many rough-and-ready methods of providing that essential link between words on a page and the reality in the nighttime sky. The latest tool to come along is, of course, the microcomputer.

Mr. Simon's package differs from most astronomy software available today in that it is aimed at astronomy students, not backyard astronomers. In essence, it combines visual demonstrations with lab exercises. Though he has keyed it to no particular text, it would be useful in any introductory course, either at the science-major or the non-science-major level.

Designed to run on Apple computers, the package contains 16 programs on a single 48k floppy. (I test-ran it on an Apple IIe with a monochrome monitor.) The 16 programs fall into three subsections: "Space Travel," "The Solar System," and "The Stars." You insert the disk, turn on the Apple, and when the disk has booted, you see an author/title credit followed by a short animated graphic that shows Jupiter as seen from Io. This gives way to the main menu, which lists all 16 programs.

The first of these, Earth Satellite, plots the course of a satellite in orbit around the Earth, given a semi-major axis between 6,500 km and 100,000 km and the orbital eccentricity. It's simple, but effective.

The next, Multi-Stage Rocket, is great fun, apart from its pedagogical value. You choose to build a 1, 2, 3, or 4-stage rocket, then decide how much fuel it holds and how fast it will burn. (The structure of the rocket is assumed to weigh nothing — more realistic would have been a fixed percentage of the total.) Your stages can hold between 1 and 1000 tons of fuel and can burn it at any rate between 0.1 and 10 tons per second. Once you've chosen your values, the computer plots two graphs, one showing altitude vs. time, the other velocity vs. time. Your goal is to reach escape velocity, 11.2 km/sec.

You quickly learn which combinations work. A 1-stager will never make it to escape velocity (given the values you are allowed to choose from), and 3- and 4-stagers are easy. I spent a lot of time trying to design a successful 2-stage and got a couple *almost* to do it. And just for realism's sake, every once in a while a carefully designed rocket won't stage properly. A buzzer goes off and a blinking message on the screen says "STAGE TWO FAILED TO IGNITE" (or whatever) — and the range safety officer destroys it in mid-flight.

Passing on to the next item in the menu, you find Expedition To Mars. This shows the Earth, Mars, and the Sun from "above." Press the space bar and the two planets move ahead in their orbits by 10 days. When you think they're positioned right to send a spacecraft from Earth to Mars (via a Hohmann transfer trajectory), you hit the "return" key. The computer then steps the planets ahead automatically in 10-day increments, tracing the course of the spacecraft on its way. If you've gotten to Mars within the 260-day limit, congratulations. If not, your crew is doomed.

Elliptical Orbit is identical to Earth Satellite except that the primary body is the Sun and the values used are astronomical units and years.

Starship is probably the hardest. For a variety of cooked-up reasons not worth going into here, you are piloting a colony starship and looking for a new star system in which to settle. You get a list of nearby stars of differing spectral types and luminosities. Your ship has a 100-person crew; it can change acceleration (+ or −) only every six months. You must find a habitable star and go there, arriving at it with zero velocity. You have supplies on board for 10 years at full crew complement.

The simulation takes account of relativistic effects, and stopping at your chosen star is decidedly difficult to do. Overshooting the target star again and again, you fiddle desperately with the acceleration while your crew steadily dwindles as months at high-G take their toll. (But look on the bright side — your food lasts longer!) Eventually, supplies run out, everybody aboard starves, and the computer wishes you a "good dinner tonight"!

Jupiter's Moons does about what you'd expect — it shows the four Galilean moons, and you can view them from above, below, or any inclination in between. Satellites lets you see a given actual moon system or design your own. (The real systems are Earth, Mars, Jupiter, Saturn, and Pluto.)

Comets shows the inner solar system and will display the motions of 10 real comets (including Encke's and Halley's), together with actual planet positions starting with the next perihelion (the computer tells you each date). The comet tails grow as they near the Sun. You can also see the path of "Your Comet" — just input the orbital parameters and the perihelion date. The next program, Solar System, displays the real positions of the planets at any date from 1500 AD to 2500 AD. You can see the system at any tilt angle and from any distance between 3 AU and 500 AU.

Spectral Types is another goodie — but one whose appeal may be strongest to those conducting an astro lab session. The computer draws a spectrum of a star; you must guess the star's spectral type, given the spectrum and two comparison spectra of your choosing. It has four levels of difficulty — straightforward spectra, Doppler-shifted ones, red-giant spectra, and "fiendish" ones. The latter can include compound spectra of unresolved double stars. This is a difficult, thought-provoking, and ultimately satisfying exercise.

Build A World lets you decide certain parameters (stellar type, orbital distance, mass, radius, albedo, etc.) for a world and then tells you its average temperature. This is a complicated problem, and you'll find you have to run it many times, varying one quantity at a time, to see what factors most affect a planet's habitability.

Double Stars shows the orbital motions of double stars for which you input masses, orbital eccentricities, and semimajor axes. The manual includes data on several real double systems.

Inside Stars plots temperature vs. radius for stars between 0.5 and 10 solar masses. Evolution of Stars amounts to an animated H-R diagram. With it you can track the evolution of a given star or of a cluster of several stars of different masses.

Finally, Spiral Galaxies draws a plain ordinary Sa, Sb, or Sc spiral on the screen at whatever inclination you like.

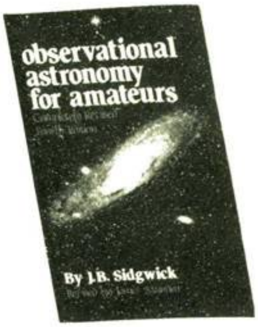
After trying the software, I have two complaints, both relatively minor. In several cases, the program-interrupt command kicks you out of the program and back to the main menu. Since many of these programs need lengthy (20- to 40-second) calculations at their start, and since you often want to halt a run that is generating nonsense, this involves a delay that soon becomes irksome. Second, in some programs, your input parameters are not displayed on the screen when you see the results of choosing them. You must always remember to write them down before you hit "return" — this also becomes tedious and annoying.

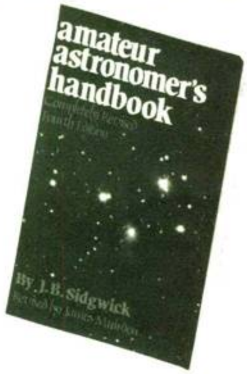
But overall, I rate this as a very good piece of software. The instructions are good, and although a number of the programs border on the simple-minded, most have excellent teaching value and a lot are outright fun to do. Although few of these programs will help your observing, they will teach you a lot about several important topics in astronomy. Astro-educators will certainly want a copy of it, but I also recommend the package to any astronomy buff who's got an Apple. *Robert Burnham.*

Early Evolution of the Universe and Its Present Structure

G.O. Abell and G. Chincarini
536 pages, hardcover, $64;
paperback, $34
Reidel (1983)

There have been dramatic advances in cosmology in recent years, both on the theoretical and observational fronts. High-efficiency detectors allow astronomers to make magnitude-limited redshift surveys, which permit cosmologists to construct three-dimensional maps of huge regions of space. The result? Matter seems to be distributed in extensive, flat, but filamentary and possibly interconnected superclusters, the interstices between vast





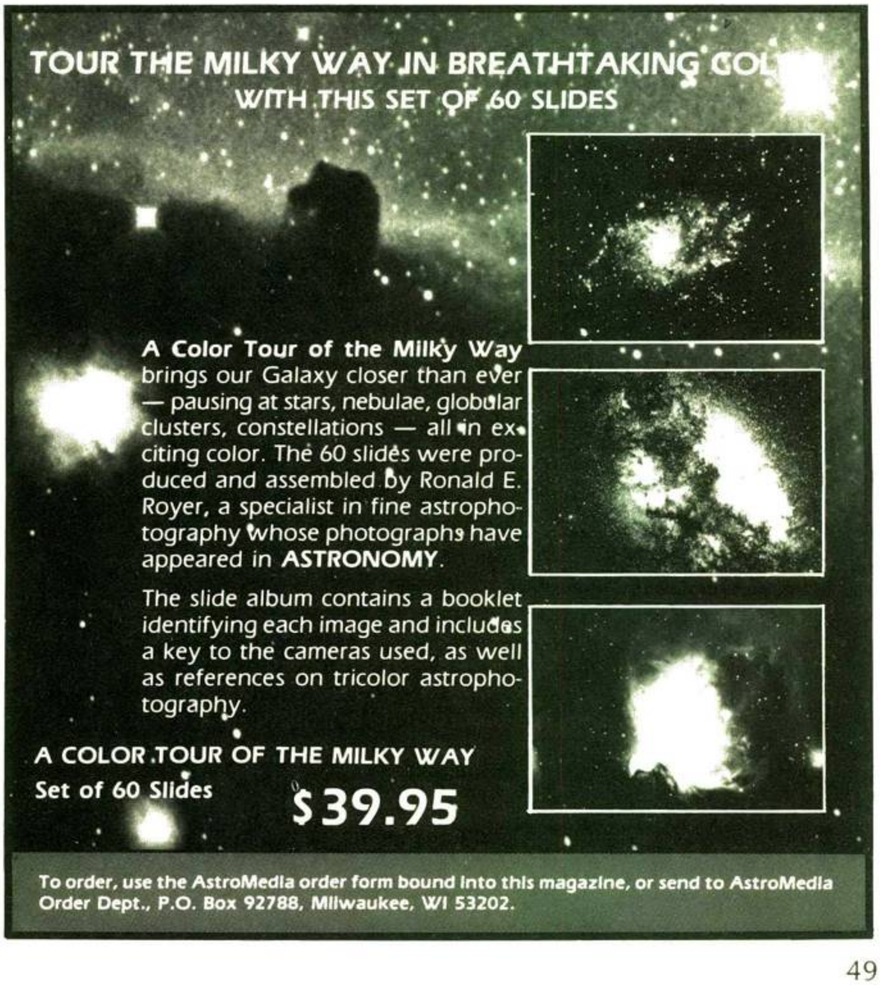
Observer's Bookshelf

Observational Astronomy for Amateurs, 4th ed.: Sidgwick. A comprehensive collection of facts on observing techniques covering the Sun, Moon and all the planets, as well as aurorae, meteors, zodiacal light and double stars. 348 pages, paperback, **$6.50.**

Amateur Astronomer's Handbook, 4th ed.: Sidgwick. Tips on mountings and drives, eyepieces, mirror and lens testing — as well as data on human vision, the Earth's atmosphere, and time-reckoning systems. 568 pages, paperback, **$10.50.**

Both books have been completely revised and updated by James Muirden and are designed as companion guides. Order them individually, or save and purchase a set of both for only $15.95.

To order, use the AstroMedia order form bound into this issue, or send to AstroMedia Order Dept., P.O. Box 92788, Milwaukee, WI 53202.



TOUR THE MILKY WAY IN BREATHTAKING COL
WITH THIS SET OF 60 SLIDES

A Color Tour of the Milky Way brings our Galaxy closer than ever — pausing at stars, nebulae, globular clusters, constellations — all in exciting color. The 60 slides were produced and assembled by Ronald E. Royer, a specialist in fine astrophotography whose photographs have appeared in **ASTRONOMY**.

The slide album contains a booklet identifying each image and includes a key to the cameras used, as well as references on tricolor astrophotography.

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voids in space.

This volume contains the proceedings of IAU Symposium 104, held in Kolymbari, Crete, in August 1982. The topics covered include a review of surveys of the universe at all wavelengths, the latest data on the isotropy of the cosmic background radiation, the possible nature of unseen matter, the dynamics and kinematics of matter in the universe, and theoretical considerations of the early universe.

ASTROCALC
5¼" diskette, $29.95
Zephyr Services
306 S. Homewood Ave.
Pittsburgh, PA 15208

ASTROCALC is a planetary ephemeris program for either the IBM PC or the Apple II, IIe, or II+ with 64k RAM. It is supplied on a single floppy, and comes with a manual that includes a complete listing of the program with a sample run.

If you are new to astronomy, the manual won't mean a lot to you — it tends to assume that you know what terms like "true anomaly" and "longitude of the ascending node" mean. To do it justice, though, the manual does provide a glossary of terms and list of reference books, the most valuable of which are the *Astronomical Almanac* and *Explanatory Supplement to the Ephemeris*.

Regardless of the technical sophistication required to understand its output, ASTROCALC is a lot of fun. I placed the diskette in the B drive of a borrowed IBM PC and LOADed it. The program first prompts for the time zone, then the time, date, month, and year. You then choose your output option: data for the Sun, Moon, all planets, individual planets, or all objects. I chose all objects. Almost before I could look up, the screen filled with the Julian day number, sidereal time, the R.A. and Dec. of the Sun, and lots more.

After reading all the stuff on the screen, I hit "enter," and after five seconds, the screen displayed a full screen list of lunar data. Mercury was next; ASTROCALC completed half of the data without difficulty, but when I hit "enter" for the second half of Mercury data, the program bombed with "Out of memory in 6260."

I hit "ctrl break" and typed RUN again, this time asking only Jupiter's vital statistics, but after displaying one screen full of Jupiter data, the program again bombed before calculating the second screen, this time at line 6390.

At this point, somewhat against my will, I was forced to get into the program. I soon realized that since nearly enough memory was available, some minor difference between the machine I was using and the standard "64k" machine had caused the problem. With MS-DOS and the BASIC interpreter in memory, there were 38,907 bytes free. ASTROCALC is a large program — 34,048 bytes — leaving too little space for storing strings and variables while computing. I deleted lines 20 through 230, 370 through 410, and 910 through 930, then tried again. This time the program ran properly and displayed two screens of data for every planet.

After computing all the data, ASTROCALC asks if you want a graphic display (rather like ASTRONOMY's Planet Data page but limited, of course, to the resolution of a screen or line printer), and then displays a summary table for the objects previously computed. After running the example supplied, and finding that the results agreed exactly, I ran the "case" for the date of this writing. The planets came out in the correct places, which was rather satisfying.

The most annoying characteristic of ASTROCALC is the spurious 16-figure "accuracy" of the output. Not only is it misleading, but it makes the output hard to read and interpret. The manual explains that the program's accuracy is limited to a few minutes of arc — just two figures beyond the decimal for positions displayed in degrees.

ASTROCALC is written in BASIC. If you do your own programming, you can alter or customize it for your own uses — it's certainly easier than working through planetary perturbation theory from scratch. The programming style is neither efficient nor compact; I suspect the program could be rewritten at half its present length. Despite this, ASTROCALC is a useful package for amateurs interested in replacing a shelf full of almanacs with a home computer, and the price is quite reasonable. *Richard Berry.*

Stars in Your Eyes
U.S. Army Corps of Engineers
23 pages, paperback, $3
U.S. Government Printing Office (1980)
[stock number 008-022-00155-7]

This little pamphlet was designed to acquaint the general reader with nine constellations north of +25° declination — Taurus, Bootes, Ursae Major and Minor, Cepheus, Cassiopeia, Draco, Cygnus, and Lyra. The text and descriptions are very elementary.

Solar and Stellar Magnetic Fields: Origins and Coronal Effects
J.O. Stenflo, ed.
564 pages, hardcover, $67.50;
paperback, $32.50
Reidel (1983)

Recent ground-based observations have supplied us with valuable information on the empirical connections between stellar rotation, magnetic activity, and age, providing a new testing ground for theories of magnetic-field generation in stellar interiors. Observations with the Einstein and IUE satellites have led to new insights concerning the role of magnetic fields in the structure and energy balance of stellar atmospheres. This volume contains the proceedings of IAU Symposium 102 held in Zurich, Switzerland, in August 1982. Topics discussed include magnetic fields in stellar photospheres, connections between rotation, magnetic activity, activity cycles, and age, theory of stellar magnetic field generation, and stellar winds in late-type stars. For professional audience only.

The Adjustment and Testing of Telescope Objectives, fifth edition
Dennis H. Taylor
112 pages, softcover, $13.50
Adam Hilger, Ltd.
(order from: Heyden & Son, 247 South 41st St., Philadelphia, PA 19104)

This edition of Taylor's 1891 classic on refracting telescopes will delight those who have been bugging rare book dealers for a copy of the 1921 or 1946 editions. If you own (or even contemplate owning) a refractor, this book is the source from which virtually everything ever printed about star testing lenses has come, and you should own it. This edition includes three interesting but dated appendices and a reprint of T. Cooke and Sons' instruction manual for disassembling and cleaning their photo-visual objectives. *Richard Berry.*

Nightwatch
Terence Dickinson
159 pages, hardcover, $24.95;
softcover, $14.95
Firefly Books (1983)

Subtitled "An Equinox Guide to Viewing the Universe," *Nightwatch* provides a basic introduction to watching the night sky. The work includes a set of star maps, information on astronomical telescopes, chapters on photography, deep-sky objects, the planets, the Moon and Sun, and comets, meteors, and aurorae.

The Guinness Book of Astronomy Facts and Feats, 2nd edition
Patrick Moore
289 pages, hardcover, $19.95;
softcover, $12.95
Sterling Publishing Co. (1983)

This second edition of the book that provides "the biggest, the first, the fastest, the farthest, the most, the smallest, and the strangest" contains information in trivia form about the planets and deep-sky objects, an extensive star catalog, and information about astronomers and observatories.

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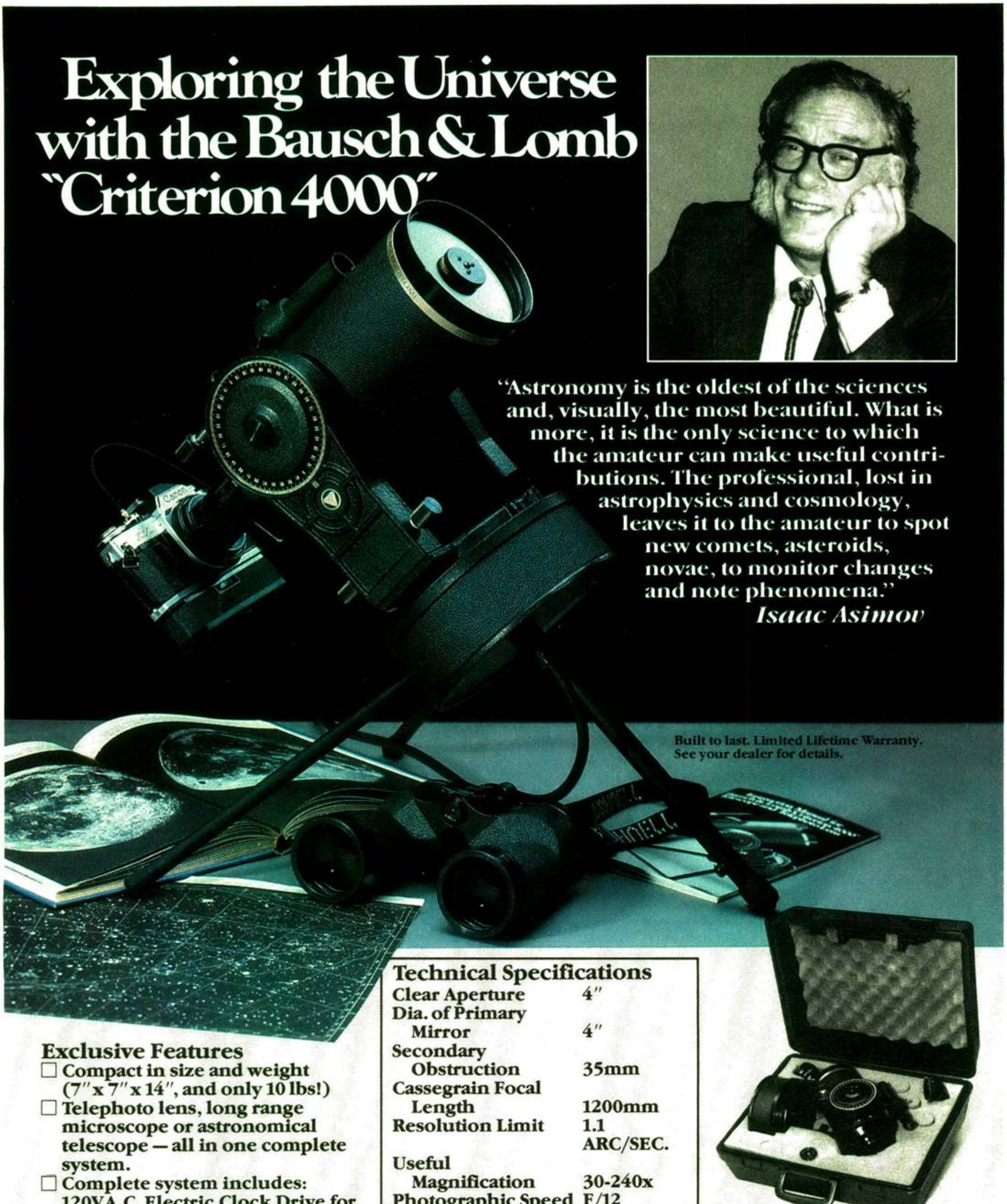

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Gazer's Gazette

Observing Uranus & Neptune

". . . In the quartile near ζ Tauri the lowest of two is a curious either nebulous star or perhaps a comet. A small star follows the comet at ⅔ of the field's distance. . . ."

". . . On Tuesday the 13th of March [1781], between ten and eleven in the evening, while I was examining the small stars in the neighbourhood of H Geminorum [1 Gem], I perceived that one appeared visibly larger than the rest: being struck with its uncommon magnitude, I compared it to H Geminorum and the small star in the quartile between Auriga and Gemini, and finding it so much larger than either of them, suspected it to be a comet. . . ."

But it wasn't a comet, as discoverer William Herschel himself later realized when the object's motions betrayed its planetary nature. Uranus, the first planet discovered since prehistoric times, doubled the size of the solar system as it was then known. Herschel's telescope that long-ago March night was a favorite of his, a homemade 6.2-inch Newtonian reflector with an f/ratio of about 14 — an instrument like many of today's backyard telescopes.

Uranus is a gas-giant world, similar to Jupiter and Saturn. It has a dense hydrogen atmosphere thousands of kilometers thick covering a mantle of ammonia, methane, and water, and a small rocky core; the uranian "surface" is actually the top of a cloud layer. The planet's rotation period is probably about 16 hours. But though they are related, Uranus is a lot smaller than Jupiter — in fact, its diameter is only about eight times that of Earth. This, coupled with its average distance from the Sun of 19.2 astronomical units (AU), means that Uranus always appears relatively dim. At magnitude 5.5, it lies just within the limits of naked-eye viewing — and was unwittingly observed more than 20 times by astronomers prior to Herschel.

Uranus has a distinct peculiarity — it orbits the Sun lying down. Its axial tilt relative to the plane of its orbit is 98°, which means that first one pole and then the other points almost directly at the Sun during the course of the 84-year uranian orbital period. Right now, it's the southern hemisphere's turn, though the "solstice" won't occur until 1985. Because we are now looking at its south pole, Uranus' disk lacks the low-contrast belts that some observers have reported during seasons when the planet was presented more equatorially. To glimpse these again we'll have to wait a decade or so — or follow closely the images from the Voyager 2 encounter about a year and a half from now.

When it comes to opposition on June 1st, you'll have a fine opportunity to get to know this outer world. Uranus is moving retrograde (westward) in southern Ophiuchus, just a short distance north of Antares, the brightest star in Scorpius the Scorpion (see the finder chart on page 83 of January's issue). Because Scorpius is rising in the southeast by the time the sky becomes dark on June evenings, the simplest way to locate Uranus is to "star-hop" from Antares.

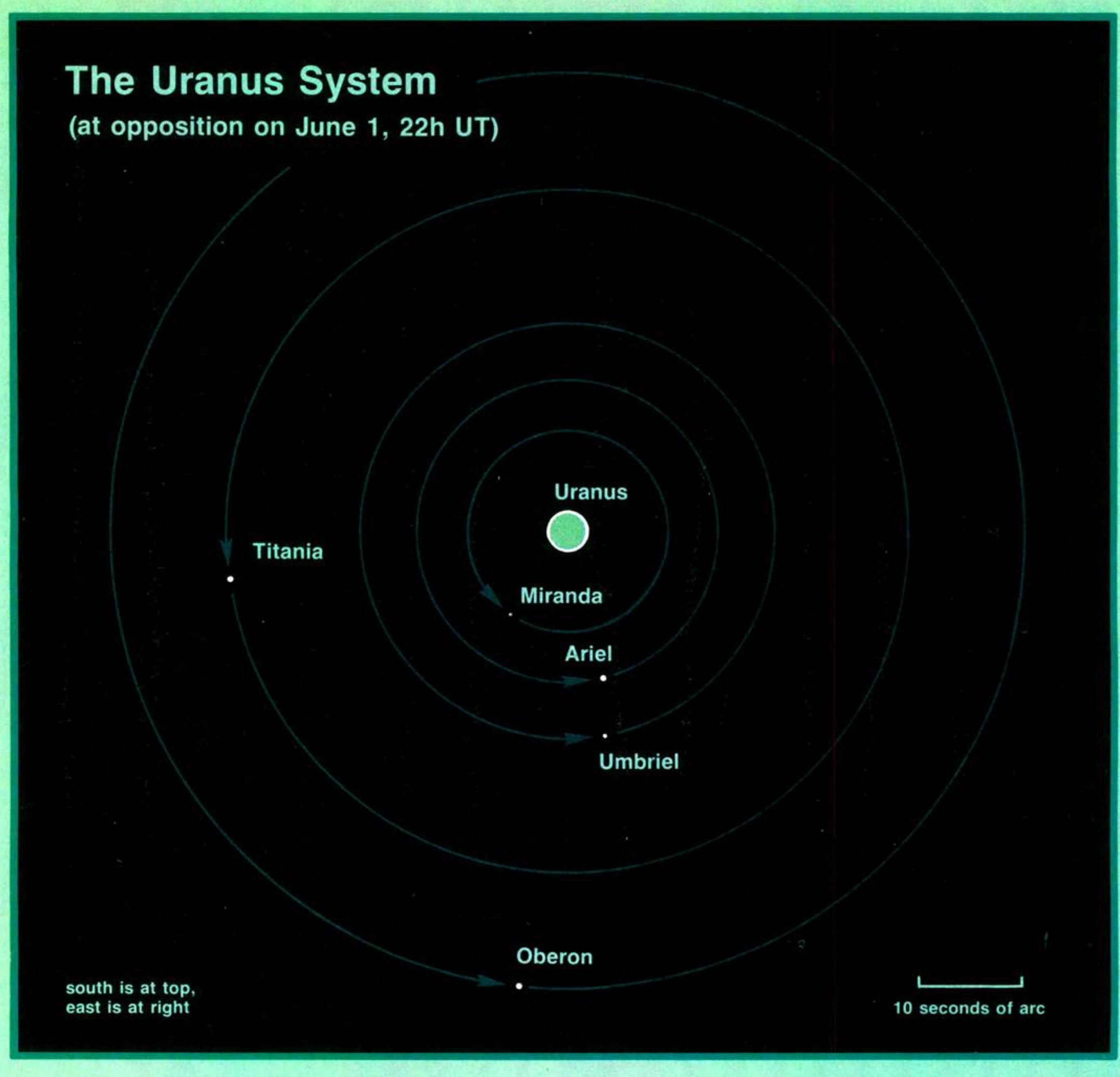
Center your scope on the star using a low to medium magnification eyepiece — 25x to 50x, say. Then slowly sweep 4° north-northeast toward Omega (ω) Ophiuchi, a 4.5 magnitude star that lies about 30′ beyond the point where you want to stop. You can then wait for 5 to 10 minutes and let the Earth's rotation bring Uranus into view — or you can scan 5 to 10 minutes of right ascension eastward for the same result. If your scope has a polar-aligned equatorial mounting and setting circles, aim it at Antares, note what the circles read, and offset the required amount. The planet is easy to see in binoculars or a good finder scope.

The bigger the aperture of your scope, the more Uranus will "pop" out of the stellar field. It has a relatively bright greenish disk 3.9″ across, and you'll probably spot it as soon as you scan into the right area. But if not, look around a bit, paying careful attention to each stellar image — or go back to Antares and try again.

When someone commented that his finding Uranus was a lucky accident, Herschel tartly replied that luck had little to do with it. His systematic telescopic sweeps had reached that particular region of sky; given the magnification he was using (227x) and the planet's visible disk, finding Uranus was inevitable. Looking at

The Satellites of Uranus and Neptune

	Magnitude (opposition)	Diameter (kilometers)	Period (days)	Distance (planet radii)
Miranda	16.5	360	1.4135	5.13
Ariel	14.4	940	2.520	7.54
Umbriel	15.3	640	4.144	10.5
Titania	14.0	1040	8.706	17.2
Oberon	14.2	920	13.46	23.0
Triton	13.5	5000?	5.877	7.13
Nereid	19	500?	359.88	112.3



The Uranus System
(at opposition on June 1, 22h UT)

it tonight, what do you think? Wouldn't *you* have spotted Uranus' non-stellar appearance immediately?

Besides its nine rings — undetectable except with the most specialized professional equipment — Uranus has five moons that range in size from 1040 km Titania to 320 km Miranda. William Herschel discovered Titania and Oberon in 1787, William Lassell found Ariel and Umbriel in 1851, and Gerard Kuiper detected Miranda in 1948. (Later research has shown that Herschel may have spotted Umbriel in 1801 and Otto Struve, Ariel in 1847.) All the moons are quite faint — Titania is the brightest at 14.0 magnitude — and to observe them requires a large scope, abundant patience, and some downright good luck.

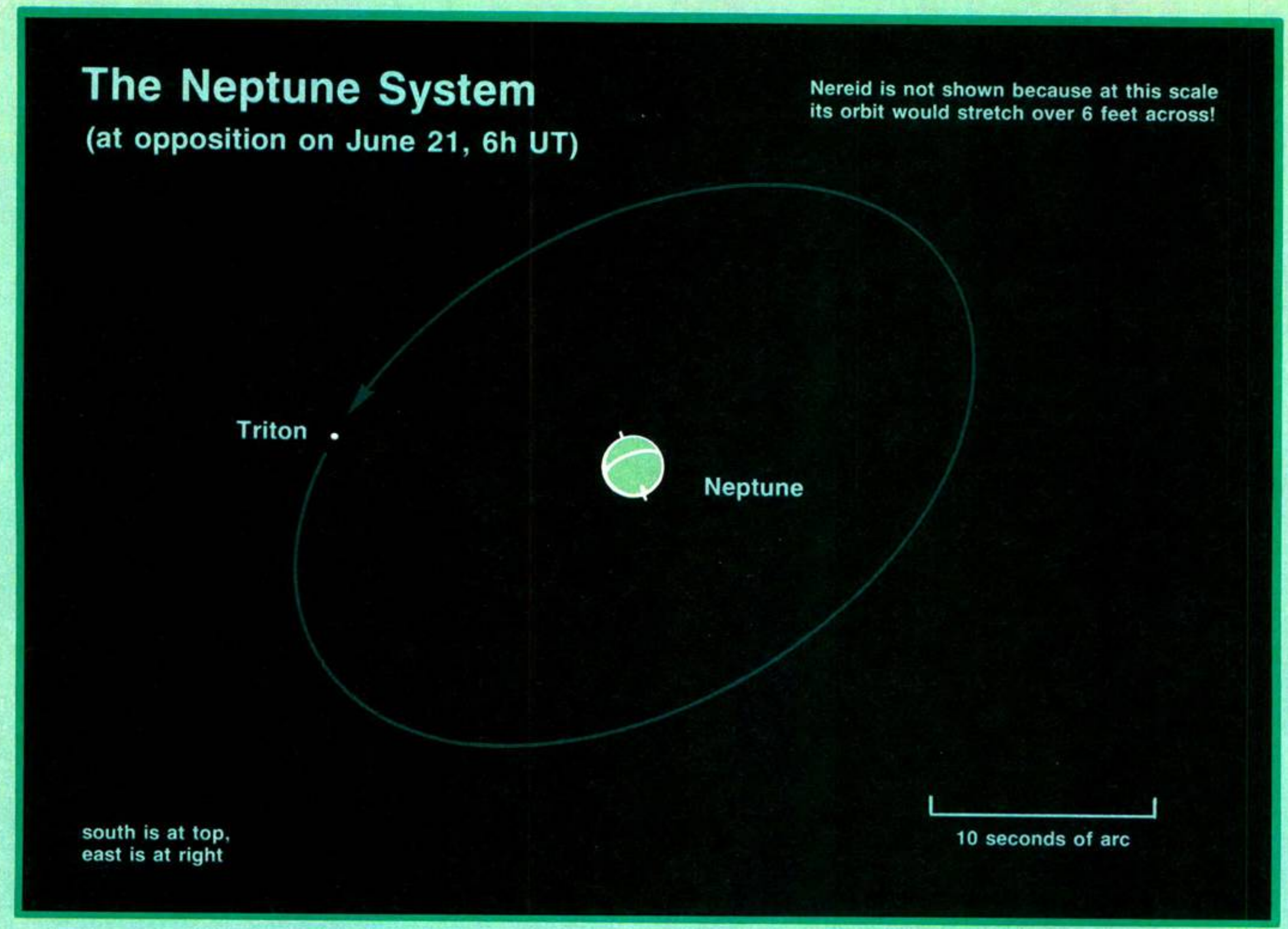
Still keen to try? Then go for Titania first: it has a maximum separation from Uranus of 17.2 radii — roughly 33 seconds of arc — and takes 8d 16.941h for one circuit. Greatest northern elongations are on June 2nd at 21h UT, 11th at 14.9h, 20th at 8.7h, and 29th at 2.5h; Titania, like all the others, revolves counterclockwise. For more data, see this year's *Astronomical Almanac*, pages F63 to F66; your public library should have a copy.

After the discovery of Uranus, the planet's motion was carefully logged and various orbits calculated. Astronomers checked into older records and found a number of pre-discovery observations, which were invaluable in giving more positions to run through the orbit-calculation mill. But then a curious result began to emerge: the longer the span of observations, the worse the orbit agreed with Uranus' actual motions. Finally:

". . . Formed a design, in the beginning of this week, of investigating, as soon as possible after taking my degree, the irregularities in the motion of Uranus which are yet unaccounted for; in order to find whether they may be attributed to the action of an undiscovered planet beyond; and if possible thence to determine the elements of its orbit, etc. approximately, which would probably lead to its discovery. . . ." (diary entry of John Couch Adams, July 3, 1841).

The young Englishman Adams worked on the problem for several years, but by 1845 he no longer had the field to himself. In France, Urbain Jean Jacques Leverrier had also set about computing where a planet might be that could account for the discrepancies of Uranus' motion — given certain reasonable assumptions as to mass, distance from the Sun, orbital iclination, and so on.

Leverrier worked out several solutions, refining his results until by the summer of 1846 he had a probable position good enough for a careful search. In England, Adams had long since reached the same stage, but was encountering much


The Neptune System
(at opposition on June 21, 6h UT)
Nereid is not shown because at this scale its orbit would stretch over 6 feet across!
Triton
Neptune
south is at top, east is at right
10 seconds of arc

pettifogging criticism from the Astronomer Royal, George Airy. Airy's opinions carried a lot of weight with British astronomers, so his disbelief in Adams' results very effectively forestalled any serious search in England until it was too late. The result? Two eager astronomers at the Berlin Observatory found the planet with Leverrier's predictions less than an hour after opening the dome! When the ensuing acrimony died down, Adams and Leverrier shared the credit for the prediction, and Johann Galle and Heinrich D'Arrest that of finding the planet — which was soon named Neptune.

Orbiting the Sun once every 165 years at an average distance of 30.1 AU, Neptune has nearly the same size and mass as Uranus. Its axis is tilted 29° to its orbit, and it rotates once every 18h 12m. Its composition, so far as anyone can tell, is probably much the same as Uranus — a thick hydrogen atmosphere overlying a mantle of methane, ammonia, and water, and a small rocky core. Since it orbits the Sun 10 AU farther out than Uranus, Neptune appears both smaller and dimmer: at opposition (June 21st) it will have a 2.3″ disk of magnitude 7.9.

Though it is visible only with optical aid, Neptune will show up in instruments as small as 7 x 50 binoculars. Moreover, it happens to be particularly easy to find during June, since it will be moving retrograde 1° north of the Trifid Nebula (M-20) in Sagittarius the Archer (see the finder chart on page 83 of the January issue). This region is low in the southeast as darkness falls, but soon gains enough elevation to be seen above the trees and houses along the horizon.

Neptune won't leap out of the starfield in quite the way that Uranus does, but its disk is pretty easily spotted all the same. If you have trouble recognizing a non-stellar disk with low power, scan into the proper field and then switch to about 100x. With this magnification, examine each star image carefully, while gently sweeping your scope back and forth across the area. (Two seconds of arc isn't large, but it is enough to look distinctly different from the pinpoint image of a star.) Once you find it, you'll be able to do it again and again on subsequent nights.

In your scope, Neptune will display a featureless disk. Careful scrutiny with sophisticated equipment — and Neptune's similarities to the other gas giants — have led astronomers to think that Neptune probably has some belt structure, but you won't see it in your scope, since it is too faint and the disk is so small.

Neptune has two satellites, Triton and Nereid. Triton was found by William Lassell a few weeks after the planet itself was discovered, but Nereid had to wait until 1949, when Gerard Kuiper detected it. Triton is definitely large, though its exact size is somewhat uncertain. It is probably about the size of Jupiter's Ganymede or Saturn's Titan — around 5000 km in diameter. It circles Neptune at a distance of 355,000 km once every 5d 21h in a retrograde direction — the only large satellite to do so. Since we observe the neptunian system from an angle (see diagram above), Triton's nearly circular orbit appears strongly elliptical. At greatest eastern or western elongation, it has a distance of about 17″ and a magnitude of 13.5.

During June, greatest eastern elongations for Triton occur on the 1st at 11.6h UT, the 7th at 8.7h, the 13th at 5.8h, the 19th at 2.9h, the 25th at 0.0h, and the 30th at 21.1h. Finding Triton will be just about as difficult as finding Titania, though the scattered light from the planet will be less since Neptune appears dimmer.

Nereid, Neptune's other satellite, orbits with direct motion once every 360 days at a distance of over 5.5 million km from the planet. It is small, perhaps 500 km in diameter, and is at magnitude 19. For backyard observers, finding Nereid is out of the question. (Kuiper found it photographically with the 82-inch at McDonald Observatory.) To know what Nereid and the rest of the system *really* look like, we'll have to wait until August 1989, when Voyager 2 will make its flyby — assuming the spacecraft is still operating. — *Robert Burnham*

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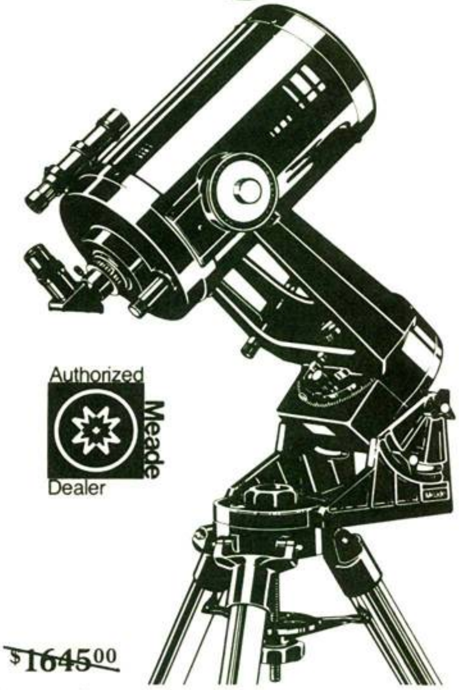

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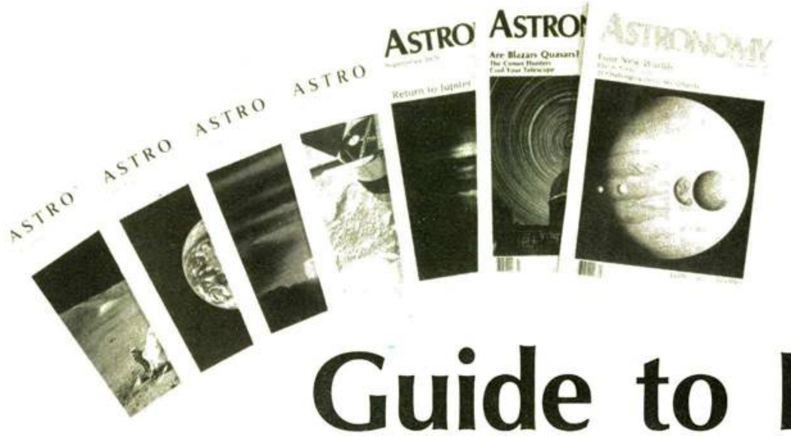

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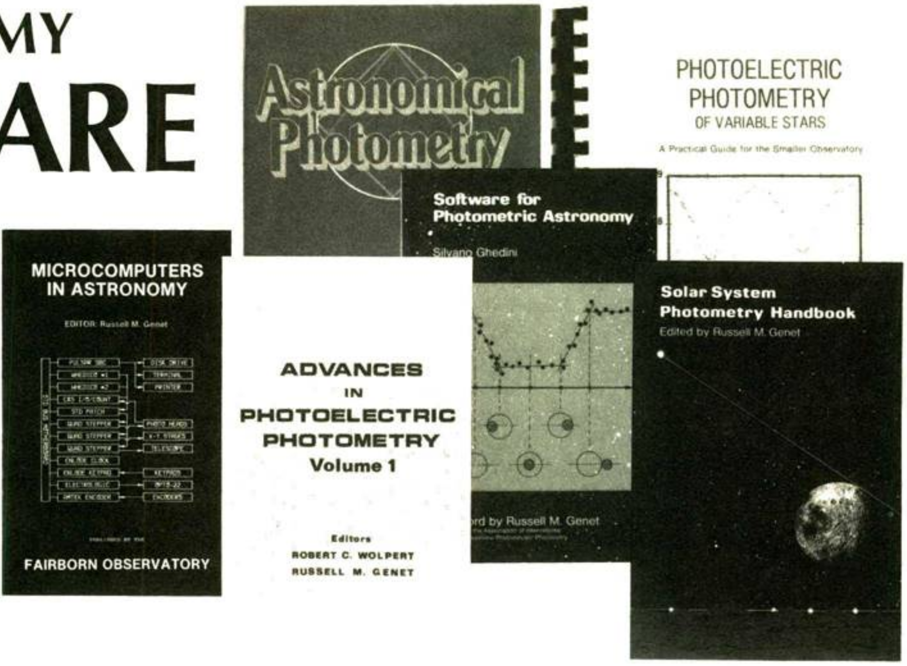
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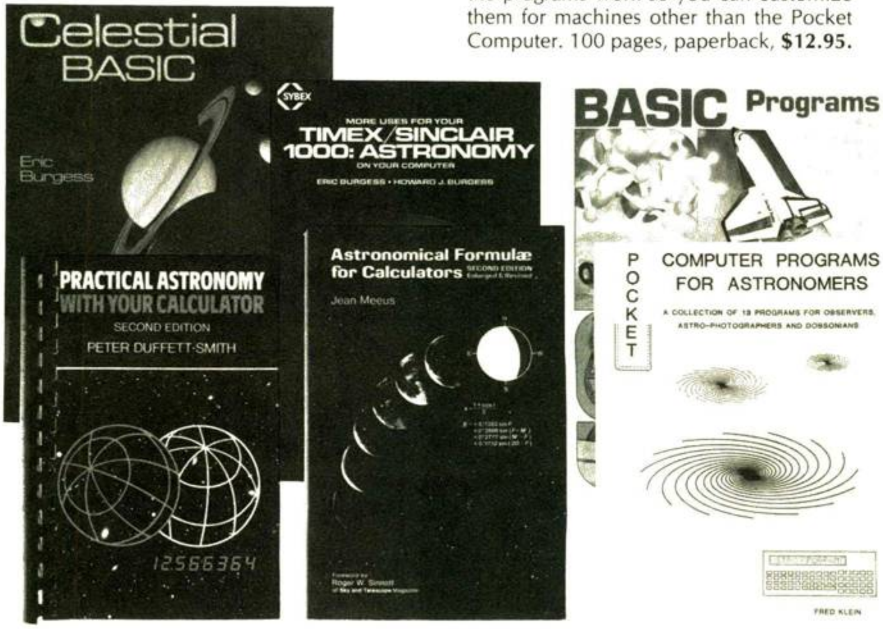
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The End of the Universe

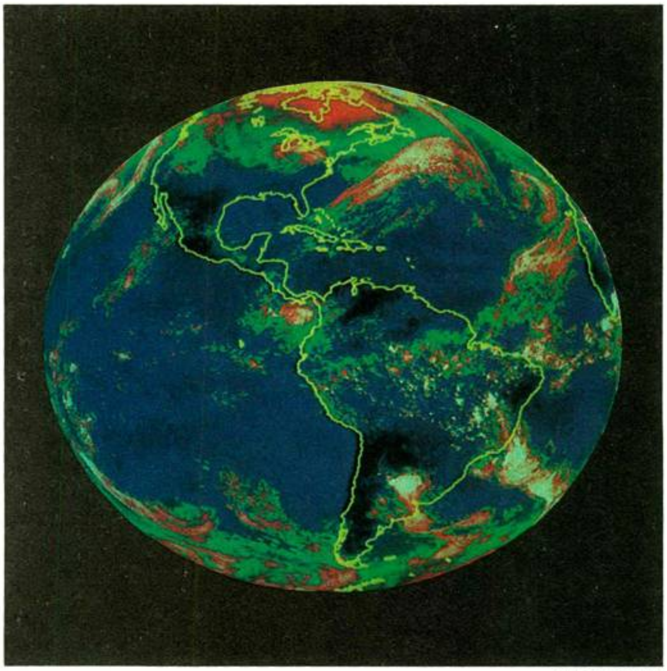
Matter simply can't last in a long-lived universe. Stars have a fleeting existence, surviving only as long as they have thermonuclear fuel to burn — on the order of 10 billion years for a star of the Sun's mass. In 100 million million (10^{14}) years or so, galaxies will run out of the gas and dust needed to make new stars. Star formation will cease, leaving a universe chiefly populated by white dwarfs, neutron stars, black holes, and planets. According to recent research in particle physics, the proton itself has a finite lifetime on the order of 10^{30} years. So white dwarfs, neutron stars, and planets will cease to exist 1,000 million million years after star formation comes to a halt. When this happens, the only survivors will be black holes. But nothing lasts forever, and black holes, too, must eventually evaporate — on the order of 10^{64} years from now for a hole containing one solar mass.

The end of matter in the universe may be a good deal closer, according to University of Chicago astrophysicist Michael Turner. Writing in the November 10, 1983, issue of *Nature*, Turner took into account the effect of magnetic monopoles, extremely massive particles thought to have been created during the Big Bang. As their name implies, monopoles carry an isolated "north" or "south" magnetic pole. These particles interact with protons and neutrons in such a way as to speed up, or catalyze, their decay.

Because of their great mass, magnetic monopoles are no longer produced in the universe. Any superheavy monopoles present today must be relics of the early universe, created within the first 10^{-35} second of the Big Bang. Turner assumed a very small flux of monopoles, corresponding to about one particle passing through a large city per year. Monopoles that run into stars, planets, and other objects can lose enough energy to stop within them. Thus, according to Turner, monopoles should gradually collect inside stars and planets, greatly enhancing the rate of proton decay.

Once in the white dwarf stage, our Sun will evaporate in a time on the order of 10 million million (10^{13}) years, depending on the monopole flux. Thus, because of monopole-catalyzed proton decay, white dwarfs will evaporate around the time that star formation comes to a halt — 1,000 million million times sooner than they would in a universe without monopoles. A neutron star will disappear in 100 billion years. As its mass decreases to around one-tenth that of the present-day Sun, the neutron star may explode, producing a display resembling the supernova that created it.

And what of the Earth? Our planet will outlive the Sun and most of the planets in the solar system, evaporating into the void a billion billion (10^{18}) years hence. Asks Turner, "Is there any escaping this fate?" Given the large number of monopoles already accreted, it's too late to worry about constructing monopole shields. "Of course," he notes, "there is always the possibility that the monopole flux is exceedingly small or that the catalysis process proceeds at a rate much, much less than predicted."



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More New Planetary Systems?

Observations providing the most direct evidence for ongoing formation of a new planetary system were recently announced by a team of astronomers from the University of California at Los Angeles, Cornell University, and the University of Hawaii. The team bases its findings on the detection of a cloud of small solid particles, with a combined mass roughly equal to that of the Earth, surrounding a very young star in the constellation Taurus. Known as HL Tauri, this star has about the same mass as the Sun and lies about 500 light-years away.

Observations made last November and December led to the discovery by Benjamin Zuckerman of UCLA, Steven Beckwith and Michael Skrutskie of Cornell, and staff astronomer Melvin Dyck of the University of Hawaii.

The particles around HL Tau reflect infrared radiation emitted by the star and scatter it toward Earth. The cloud of particles appears to extend between 80 and 160 astronomical units from HL Tau. One astronomical unit is the distance between the Earth and the Sun.

The astronomers used a technique called speckle interferometry, which allowed them to resolve extremely small angles in the sky. The apparent diameter of the scattering cloud around HL Tau is about two times larger in the east-west direction than in the north-south direction. "This distribution is just what we would expect from a disk-shaped cloud, which in this case lies at a tilted angle with respect to our line of sight — that is, the disk as seen from Earth is neither exactly edge-on nor face-on," Beckwith says.

From the amount of scattering at different wavelengths, the astronomers can determine the size of the particles — in this case, less than a few thousandths of a millimeter across. Pressure from the star's radiation should sweep such particles from the center of the disk, but HL Tau is so young — about 100,000 years — that only a small hole could have been produced by now.

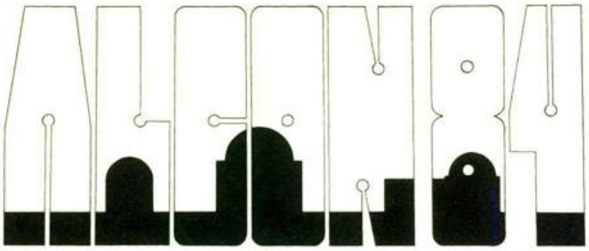
In addition to HL Tau, the team detected scattered infrared light indicating solid material around another newly formed star, R Monocerotis, in the constellation Monoceros. The angular size of the cloud in the R Mon system is similar to that around HL Tau, but because R Mon is four times farther away from Earth, the R Mon cloud must be four times larger than the one about HL Tau.

The new discoveries are somewhat similar to those announced by NASA reporting evidence of solid particles around the stars Vega and Fomalhaut. Because Vega and Fomalhaut are much closer to the Earth than either HL Tau or R Mon, the particle clouds around the former stars appear to cover a much larger area in the sky.

Nonetheless, the cloud masses around HL Tau and R Mon are both much larger than those observed around Vega and Fomalhaut. Measurements indicated that the mass detected around Vega and Fomalhaut was only a percent or so of the Earth's mass. But the total mass detected in the cloud near HL Tau is roughly equal to the Earth's mass, and that around R Mon is roughly five times greater.

The giant planets in our solar system, Jupiter and Saturn, are composed mainly of hydrogen and helium, but the dust particles detected around HL Tau and R Mon contain elements that are cosmically less abundant, such as oxygen and silicon. From their observations, astronomers infer a hydrogen mass around HL Tau and R Mon comparable to the mass in the giant planets. Thus conditions appear favorable for the formation of a planetary system similar to our solar system.

Investigating several other stars that might be ringed by planets, including T Tau, DG Tau, and V 380 Ori, the team found no evidence for solid particles, although these stars are similar in mass and age to HL Tau and R Mon. Two years ago, Dyck and Zuckerman discovered a faint, cool companion to T Tau. They believe it is a small protostar, but some other astronomers interpret it as a giant protoplanet.



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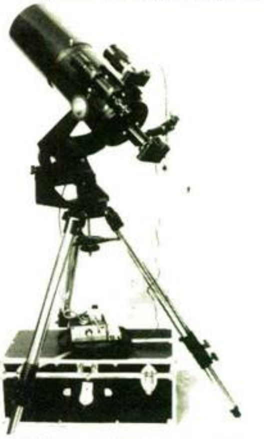

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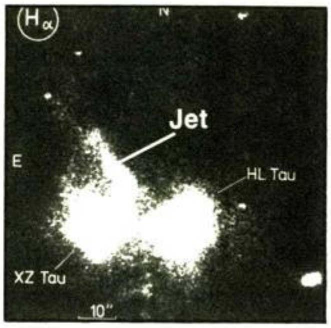

HL Tau (right) may be the center of a forming solar system. The star's dense disk of material may create the elongated "jet" of hydrogen gas by focusing its stellar wind. Photo by Reinhard Mundt and Josef Fried.

"Theoretically, it should be very difficult to form disks in binary star systems such as T Tau," said Zuckerman. "The lack of evidence for a disk around T Tau is consistent with such theories. We do not yet know why DG Tau and V 380 Ori show no signs of planetary material. There is a possibility that small dust particles have had time to condense into larger particles, or even planetesimals, which, however, would not show up in our observations."

Galaxy-Sized Primordial Clouds Detected

An international team of astronomers using the Multiple Mirror Telescope in Arizona has made the first measurement of the size of possible proto-galaxies in the early universe. These diffuse galaxy-sized gas clouds were detected at cosmological distances with an observational technique involving a natural gravitational lens.

Craig Foltz of the University of Illinois, Ray Weymann of the University of Arizona, Frederic Chaffee of the Smithsonian Institute, and Hermann Josef Roser of the Max Planck Institut fuer Astronomie in Heidelberg obtained spectra of two quasar images to study clouds of intergalactic material lying between the Earth and a single quasar 11 billion light-years away. Astronomers believe the double quasar image is formed by the deflection of the quasar's light by a galaxy, or cluster of galaxies, between the telescope and the quasar — a phenomenon known as a gravitational lens. (See "Gravity Lenses" in the July 1981 issue.)

The observing team found evidence not only for a cluster of galaxies suspected to be the lens at 9 billion light-years from Earth, but also for the presence of intergalactic clouds lying beyond the cluster at a distance of approximately 10 billion light-years.

Making use of the unusual geometry provided by the gravitational lens, Folz and his colleagues estimated that the clouds are at least 15,000 light-years across, or about the size of a small galaxy. (By comparison, the Milky Way Galaxy is about 100,000 light-years in diameter.)

The extreme distance of these clouds from Earth, as well as evidence from other investigations, suggests they may consist of primordial material representative of an early state of the universe and may be the type of material out of which all other matter has evolved. Such clouds have long been known to exist, but only crude estimates of their sizes could be made. This is the first time such clouds have been shown to have the size of galaxies.

If other examples of such intergalactic clouds can be found, and if astronomers can make accurate estimates of their size, they could provide keys to understanding how galaxies formed in the early universe.

Dam-Busting May Cause Stellar Outbursts

Flare-ups that regularly recur in some double star systems result when a "dam" that blocks the flow of gas between them suddenly heats and bursts — so say several astronomers from the University of California, Santa Cruz, and Queen Mary College, London.

In these stellar systems, gas streams between the two stars as gravitational force from one tears off and attracts the outer layers of its partner. The loosened material collects in a disk as it falls inward, in effect creating a "dam," which traps and stores increasing amounts of energy until it finally gives way.

The release of the trapped material causes a sudden, dramatic brightening of the star system, a process "very much like an avalanche," according to John Faulkner, a UC Santa Cruz astronomer. Similar events may occur in quasars and other exotic objects that sometimes release a burst of luminosity, he says.

Faulkner and his colleague Douglas Lin, in collaboration with John Papaloizou of Queen Mary College, recently published a series of two papers detailing their "hot dam" model in the *Monthly Notices* of the Royal Astronomical Society; a third article is currently in preparation. Their work seeks to explain the temporary brightening of star pairs known as dwarf novae.

Unlike a supernova, in which a single star expires in an explosion of such brilliance that it can outshine a galaxy of 100 billion stars, a dwarf nova is a binary star system that experiences more modest, and repetitive, brightenings. Typically, a dwarf nova flares every few months and shines 10 to 100 times brighter than usual.

One member of such a system is either a white dwarf or an extremely compact, Earth-sized, hot, blue star; its less massive partner is a cooler, Sun-like, yellow star. Over the system's lifetime, the distance between the circling stars shrinks. Eventually, the two stars draw so near to each other that the gravitational pull of the compact star rips away its companion's loose outer layers. The freed gas, almost exclusively hydrogen, spirals down toward the compact star and spreads into a thin sheet of gas — an accretion disk — around it.

Theorists have proposed that the "engine" powering quasars and certain eruptive galaxies consists of an accretion disk being drawn into a black hole. Material in the disk, before being devoured by the black hole, is agitated and heated by friction. Similarly, in dwarf novae much of the light from the system can come from the luminous hydrogen in the accretion disk. Before the infalling gas settles onto the compact star, it must work its way from the outside edge, where the gas first joins the disk, until it reaches the disk's inner edge.

Faulkner, Lin, and Papaloizou propose that the way material moves through the accretion disk controls the recurrent brightening of these systems. "You need to interrupt the flow, so that it's sporadic," says Faulkner. "Our model provides a way of naturally interrupting the flow."

The disk gas continues to orbit, retaining some of the motion it had before being torn from its parent star. Different parts of the disk, though, move at different speeds, causing friction and heat. When part of the disk gets hotter, the warmth is initially trapped because the hydrogen gas doesn't let the heat radiate away. As the gas becomes hotter, it also becomes increasingly opaque, thus creating a self-insulating heat trap.

"When local heating occurs, it spreads like crazy and the whole disk gets involved," Faulkner says. The thermal "runaway" is also aided by the fact that hydrogen becomes more viscous as it gets hotter. Increasing viscosity means greater frictional heat which in turn means more opacity, more viscosity, and more friction. As more and more of the gas's orbital motion is turned into heat, its temperature climbs steadily.

The disk finally reaches a temperature hot enough to ionize the hydrogen — the atoms dissociate into individual protons and electrons. When this happens, the disk suddenly becomes transparent. All the pent-up energy is released in a luminous burst, and the gas, whose orbital energy was stolen to make heat, plummets onto the compact star, emptying the reservoir for the next buildup.

Faulkner says, "Our mechanism provides natural time-keeping scales. It takes just about as long for the disk in our model to recover as is seen in nature."

Not only does the "hot dam" reproduce the observed pattern of outbursts, it can also account for the peculiar deviations from regular patterns of rebrightening that certain dwarf novae display. Moreover, the hot dam model differs significantly from previous explanations. "In the past," Faulkner says, "people sought the triggering mechanism where the bulk of the material lies."

The hot dam proponents believe that the outburst can occur at any point in the disk because the runaway conditions will spread so rapidly. "If you want to set off a keg of dynamite, it's best to lay a long fuse — and so it is in the disk," says Faulkner.

NRAO Selects Site for Radio Telescope Network

The NRAO will place the operations center for its planned network of high-resolution radio telescopes, called the Very Long Baseline Array (VLBA), in Socorro, New Mexico. Socorro is close to the Very Large Array (VLA), an existing system of 27 radio telescopes. Two of the proposed VLBA antennas will also be located nearby. This arrangement allows combined operation of the VLBA and of the VLA.

The new array itself will consist of 10 radio telescopes, each about 80 feet in diameter, placed at locations from Puerto Rico to Hawaii. By computer processing the signals received simultaneously from all 10 telescopes, astronomers will be able to view the universe with a resolution that surpasses all currently planned or completed astronomical instruments — optical or radio.

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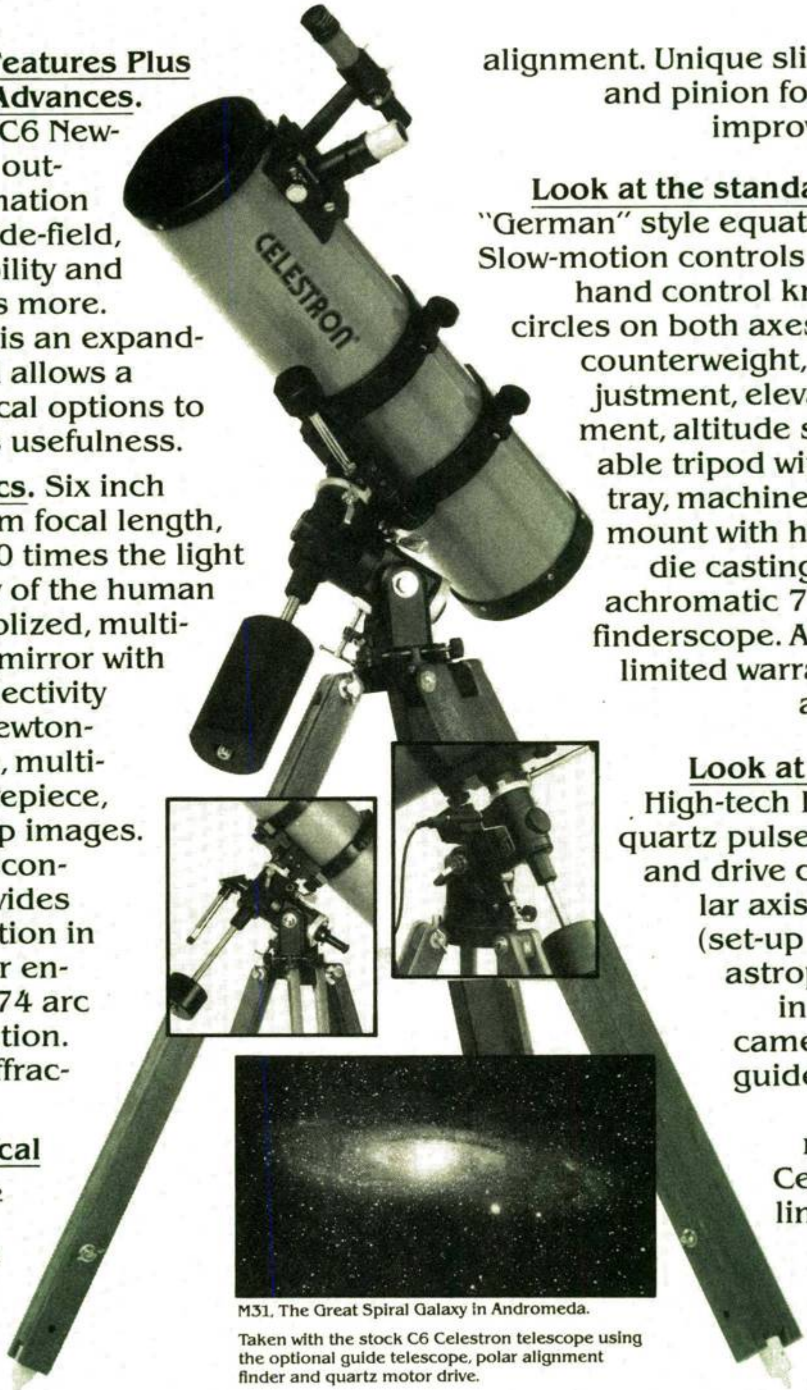

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ASTROCALENDAR

May 23-25
IAPPP Big Bear Symposium, Camp Oaks, Big Bear Lake, California (same place as Riverside Telescope Maker's Conference). Contact: Rev. Donald L. Rohe, 957 West Marshall Blvd., San Bernardino, CA 92405. Phone (714) 383-4731 or (714) 883-7923.

May 25-28
Riverside Telescope Maker's Conference, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92505.

May 30-June 3
Texas Star Party, Fort Davis, Texas. Contact: TSP '84, Dept. A, 128 N. Commerce, Burleson, TX 76028.

June 8-9
14th Annual Apollo Rendezvous and Telescope Fair, Dayton, Ohio. Sponsored by the Miami Valley Astronomical Society and the Dayton Museum of Natural History. Contact: Chairmen, Apollo Rendezvous, P.O. Box 287 Dabel Branch, Dayton, OH 45420.

June 11-13
Society of Amateur Radio Astronomers 1984 Symposium, National Radio Astronomy Observatory, Green Bank, West Virginia. Contact: Bob Patterson, 1548 Bell Flower Ct., Stone Mountain, GA 30088.

June 19-23
Southeastern Planetarium Association Annual Conference, Bradenton, Florida. Hosted by the Bishop Planetarium. Contact: John Hare, Director, Bishop Planetarium, 201 10th St. W., Bradenton, FL 33505. Phone (813) 746-4132.

June 22-24
Convention of the Mid-States Region of the Astronomical League, Washington University, St. Louis, Missouri. Contact: Convention Chairman, Stephen Best, 6943 Amherst Ave., University City, MO 63130; Papers Chairman, Mark Jones, 621 Parker Dr., Ballwin, MO 63011.

June 29-30
Burke Lake Telescope Meet, Burke, Virginia. Sponsored by the Northern Virginia Astronomy Club. Contact: John S. Huggins, 5608 Flag Run Dr., Springfield, VA 22151.

June 30
Northeast Regional Astronomical League Convention, Sperry Observatory, Cranford, New Jersey. Sponsored by Amateur Astronomers, Inc. Contact: Roger Tuthill, (800) 223-1063 (toll-free).

July 7-12
Joint Meeting of the Astronomical Society of the Pacific, the Western Amateur Astronomers, and the Astronomical Association of Northern California, University of California, Santa Cruz, California. Contact: Summer Meeting, A.S.P., 1290 24th Ave., San Francisco, CA 94122.

July 10-14
Case for Mars II, Boulder, Colorado. A workshop on the future of manned missions to Mars, sponsored by the Mars Institute of the Planetary Society, the Boulder Center for Science and Policy, and the University of Colorado Space Interest Group. Contact: Case for Mars, P.O. Box 4877, Boulder, CO 80306.

July 12-14
Microcomputers in Astronomy II, Fifth annual IAPPP-Fairborn Symposium, Fairborn, Ohio. Contact Russell M. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.

July 16-24
Spaceweek '84. Programs in many cities need your help. Contact: Spaceweek National Headquarters, P.O. Box 58172, Houston, TX 77258.

July 16-24
Florida Spaceweek '84. State-wide celebration of the 15th anniversary of the Apollo 11 Moon mission. Contact: Florida Spaceweek Committee, 993 Macco Rd., Cocoa, FL 32927.

July 16-August 3
Astronomy Institute for Pre-College Teachers, Austin, Texas. Contact: Mary Kay Hemenway, Department of Astronomy, University of Texas, Austin TX 78712. Phone (512) 471-4461.

July 20-31
International Workshop on Astrophotography, Oteppe, Belgium. Limited to young amateur astronomers ages 16-24. Contact: Luc Vanhoeck, Belgian Astronomical Association (VVS) Section Astrophotography, Elsbos 16, B-2520, Edegem, Belgium.

July 28
Stellafane, Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.

July 28
Ohio Turnpike Astronomers Association Convention, Hiram College, Hiram, Ohio. Sponsored by the Cuyahoga Astronomical Association. Contact: Gary Kader, 2580 Northglen Dr., Westlake, OH 44115.

August 1-4
ALCON '84, National Convention of the Astronomical League, Carroll College, Waukesha, Wisconsin. Hosted by Milwaukee Astronomical Society. Contact: ALCON '84, P.O. Box 275, Mequon, WI 53092.

August 1-4
Astromart '84, an astronomy equipment fair held simultaneously with ALCON '84. Carroll College, Waukesha, Wisconsin. Hosted by ASTRONOMY Magazine. Contact: Dana-Lynne Terry, Advertising Coordinator, ASTRONOMY Magazine, P.O. Box 92788, Milwaukee, WI 53202. Phone (414) 276-2689.

August 6-10
Spitz Space Systems' Summer Institute in Planetarium Education, Chadds Ford, Pennsylvania. Contact: 1984 Planetarium Summer Institute, Spitz Space Systems, Inc., Rt. 1, Chadds Ford, PA 19317.

August 9-12
Convention of the Southeast Region of the Astronomical League, Pensacola, Florida. Co-hosted by Escambia Amateur Astronomer's Association and the University of West Florida. Contact: Merry E. Wooten, 6235 Omie Circle, Pensacola, FL 32504.

August 17-18
Near-IR and Solid-State Photometry Symposium, Lowell, Michigan. Hosted by IAPPP and Optec. Contact: Russell M. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.

August 24-26
Connecticut River Valley Astronomers' Conjunction, Northfield Mountain Center, Northfield, Massachusetts. Contact: Jack Megas, 311 Surrey Rd., Springfield, MA 01118.

August 24-26
Starfest '84, Third Annual Observing Convention of the North York Astronomical Association, The River Place, Mount Forest, Ontario, Canada. Contact: Andreas Gada, 145 St. George St., Toronto, Ontario, Canada M5R 2M1. Phone (416) 922-6294.

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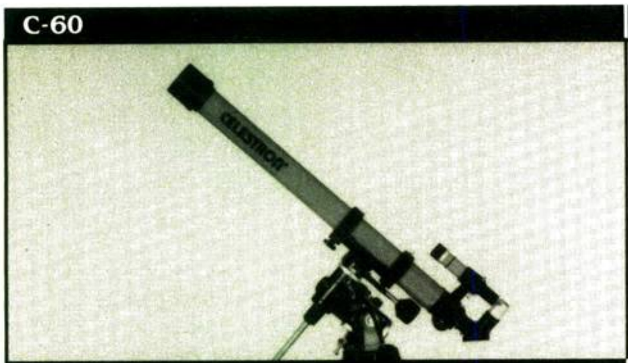

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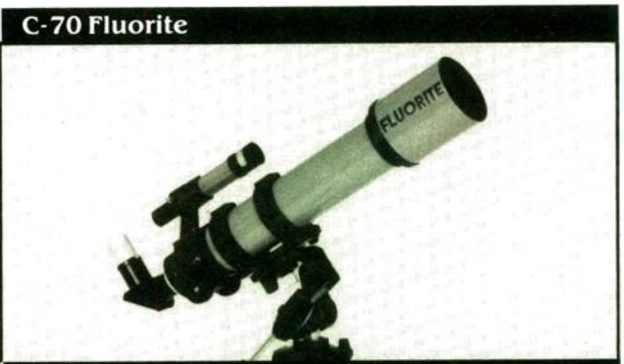

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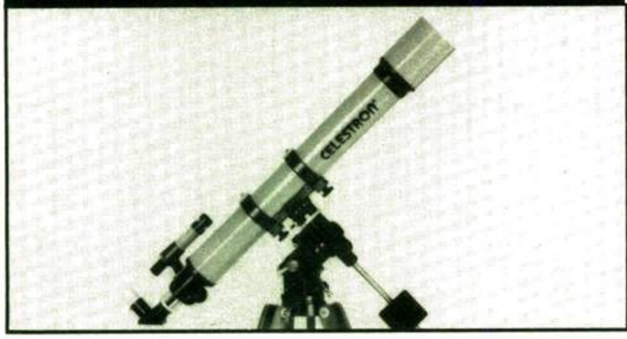

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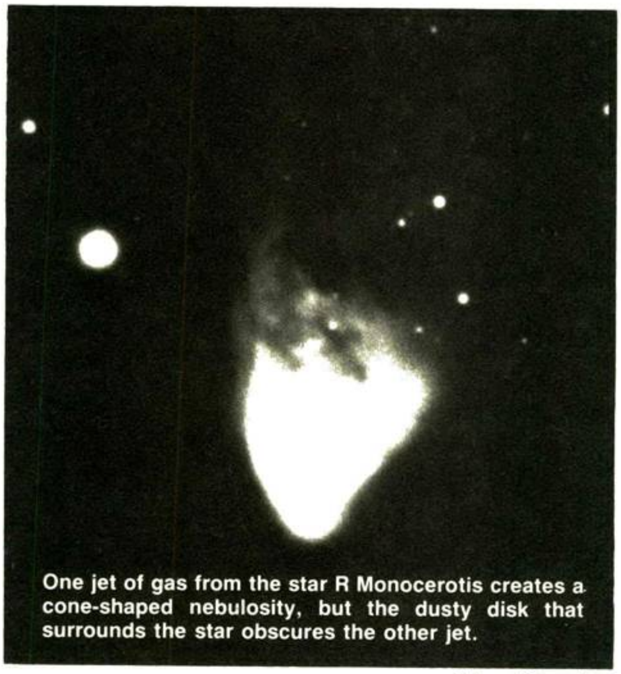
Cosmic Jets: Bipolar Outflows in the Universe

by Luis Rodriguez

Like many objects in the universe, our Sun ejects material into the space around it. This outflow of charged particles, known as the solar wind, steals only a modest amount of mass from the Sun, and has no long term consequences on our star's evolution. During the next five billion years, the Sun will lose only about 1/10,000 of its mass through the solar wind. There are, however, stars with more substantial outflows of material — their powerful "stellar winds" carry away a significant fraction of their mass. Even so, these stellar outflows constitute only small-scale mass loss. For instance, astrophysicists believe that at the end of their lives most stars undergo processes by which they eject their outer layers to the interstellar medium. And on an even larger scale, consider the extremely energetic events that occur in the nucleus of an active galaxy or quasar. There, an object of as yet unknown nature, but which astronomers frequently equate with a supermassive black hole, ejects quantities of matter millions of times greater than that ever ejected by solitary suns. Although mass ejection phenomena occur over a great range of size, astronomers have recently found some tantalizing similarities between these extremes in the mass-loss "spectrum."

The simplest type of outflow ejects material equally in all directions, a situation physicists describe as *isotropic*. But for reasons not fully understood, nature seems to favor another, apparently more complex, geometry for cosmic outflow. In a wide variety of phenomena, ranging in size from light-years to megaparsecs, matter flows outward from a central source in two oppositely directed streams. This configuration is generally referred to as *bipolar*.

Radio galaxies were the first clear example of a class of sources with bipolar structure. Even early in the development of radio astronomy, it was clear that some visible galaxies were also powerful emitters of radio waves. In 1953, Roger Jennison and M.K. Das Gupta found to their surprise that the radio emission from an intense source in Cygnus did not originate from the associated elliptical galaxy, but from two gigantic lobes on either side of it. These radio-emitting lobes are far larger than the galaxy itself. Studies of the intensity and polarization of these radio lobes indicated that the emission came from electrons spiraling in magnetic fields at velocities close to that of light. This type of emission, known as *synchroton radiation*, was discovered in terrestrial particle accelerators.



One jet of gas from the star R Monocerotis creates a cone-shaped nebulosity, but the dusty disk that surrounds the star obscures the other jet.

Palomar Observatory

Where do the radio lobes come from? Did they form simultaneously with the galaxy or are they of recent creation? In many cases, sensitive radio observations made with high resolution revealed narrow channels between radio lobes and the central regions of the galaxy. These narrow jets of plasma connect the huge radio-emitting lobes with the center of the galaxy.

Astrophysicists generally believe that the ultimate power source for these systems resides in the nucleus of the related galaxies. Somehow, twin jets of particles stream out of the galaxy's core at a substantial fraction of the speed of light, feeding hot plasma to the distant lobes. Roger Blandford of the California Institute of Technology and Martin Rees, an astrophysicist at England's Institute of Astronomy at Cambridge, have proposed a model for this configuration. Imagine a spinning disk-shaped cloud of gas surrounding the "central engine" in the galaxy's core, the power source of the outflows. Even if the central object ejects matter in all directions, the surrounding disk will confine the flow. Gas can work its way out of the disk by flowing in the direction of least resistance — along the rotational axis of the gas cloud. Astronomers have used computer models to follow the evolution of an isotropic explosion occurring in the center of a gaseous disk. As expected, the explosion does not expand greatly in the plane of the disk, but creates two oppositely directed streams of high-velocity particles. These jets squirt out *perpendicular* to the plane of the gas cloud — a bipolar ejection.

The jets of active galaxies are enormous, their radio-emitting lobes often extending for hundreds of thousands of light-years. But bipolar ejection also occurs in objects of much smaller dimensions. In the past few years, astronomers have found that newly formed stars lose great amounts of material to their surroundings. Deeply embedded in dense molecular clouds, these young stars are only rarely observable in the visible. In 1980, a team led by University of Massachusetts astronomer Ronald Snell discovered bipolar gaseous outflows in the molecular cloud L1551. That same year, Paul Ho, James Moran, and I also found evidence for bipolar jets in Cepheus A, another molecular cloud containing extremely young stars. Viewed naively, this phenomenon is structurally similar to that occurring in quasars and active galaxies. Astronomers have since found many more cases, and the situation is usually the same. Typically, there are two streams of molecular gas, one of which emits radio waves that are Doppler-shifted toward slightly shorter wavelengths (hence directed toward us), while the other radiates at slightly longer wavelengths (hence directed away from us). At the center of this configuration there is always a compact object emitting strongly in the radio or infrared, presumably the outflow's energy source. If the similarities between the outflows of radio galaxies and newborn stars are intriguing, the million-fold difference in size is even more unexpected.

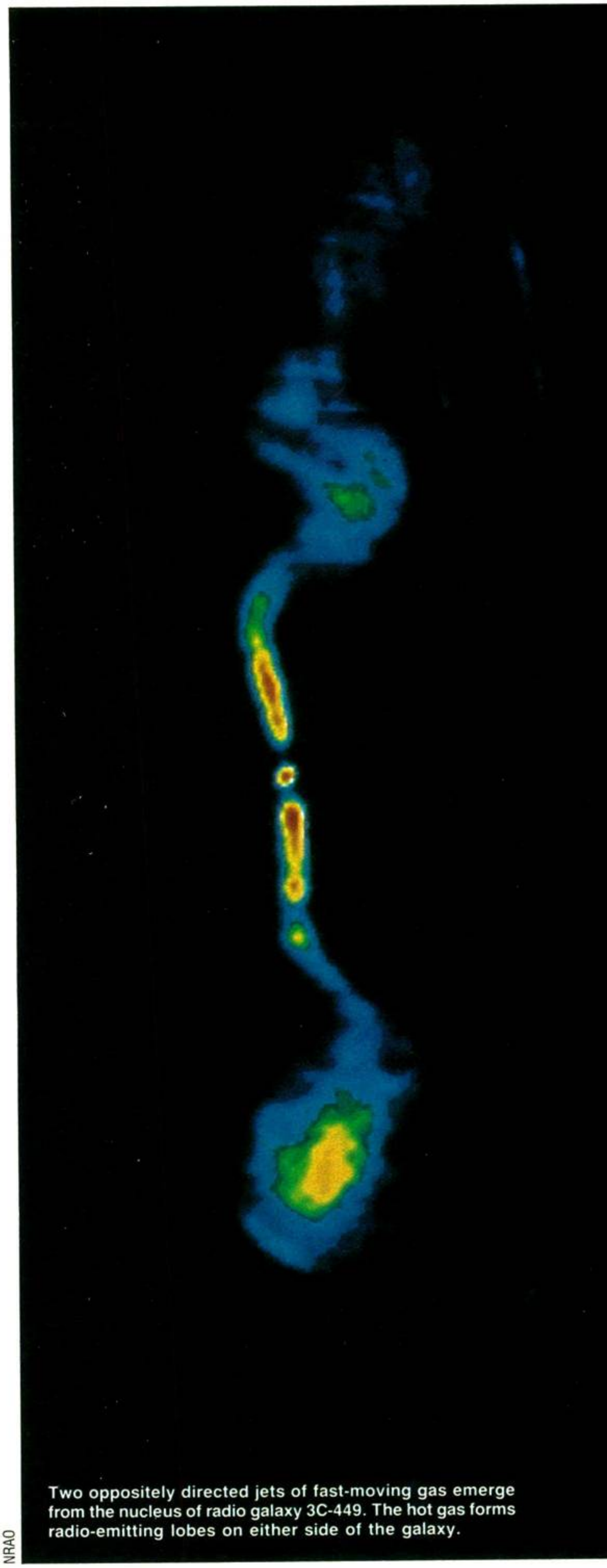
What produces the bipolar appearance of these outflows? Theoreticians like Arieh Konigl at the University of California and Jorge Canto at Mexico's Universidad Nacional argue that, as in the radio galaxies, a disk-shaped cloud surrounds the central object and transforms its isotropic outflow into a bipolar one. Jose M. Torrelles and his co-workers have found compelling observational evidence that favors this model. Many of the regions they studied show toroidal gaseous structures of interstellar dimensions (tenths of light-years) around the central star. As expected theoretically, most of these doughnut-shaped clouds lie perpendicular to the axis of the outflow.

Some bipolar outflows associated with the young, visible, T Tauri-type stars seem to be "focused" into a bipolar form very close to the star. Either these stars intrinsically emit their material in oppositely directed streams, which would be exotic indeed, or something small and nearby is altering a more typical, isotropic stellar wind. If the second possibility is the correct one, it may have far-reaching implications. If, as in other cases, these jets result from an isotropic outflow confined by a disk of gas, the disk must have circumstellar dimensions — similar in size to our solar system. T Tauri stars formed recently, and they may be surrounded by a nebula from which planets may condense in the future. This protoplanetary system would be shaped like a disk and could be responsible for changing the isotropic wind of a young star into twin jets of gas.

Astronomers have also found that vigorous bipolar outflows are not necessarily limited to stellar youth — apparently, nature likes to repeat a good phenomenon whenever possible! In 1978 a group of astronomers led by Bruce Margon of the University of Washington obtained spectra of Stephenson-Sanduleak 433, a star then believed to be a little peculiar, but not particularly strange. But SS 433's spectrum was absolutely bizarre. Its bright emission lines changed not only in intensity but, most importantly, in wavelength. Large shifts in wavelength usually imply that the emitting gas has large velocities; in the case of SS 433, the derived velocities were about one-fourth the speed of light!

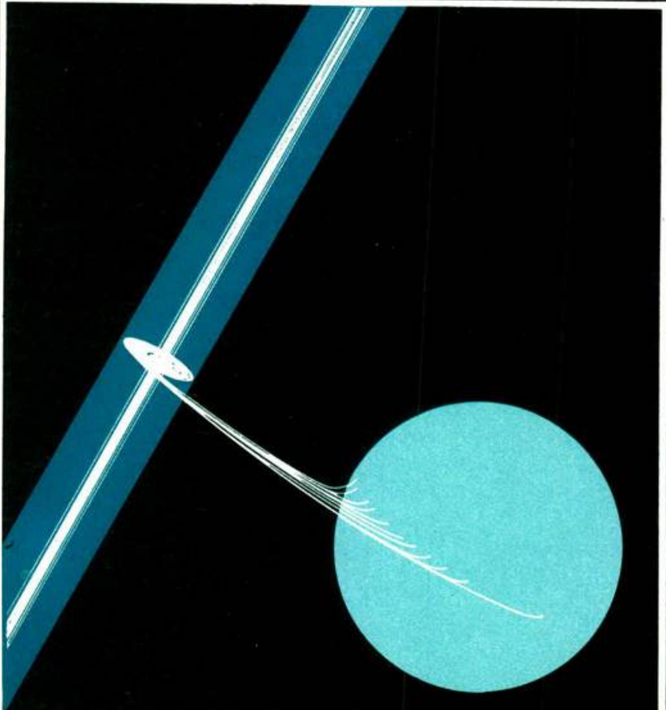
Once enough data accumulated, it was possible to present models of the system. One of the models, first proposed by Mordehai Milgrom of Israel's Weizmann Institute of Physics, requires an evolved binary system made up of a normal star and a collapsed object, either a white dwarf or a neutron star. In the model, the compact object accretes gas from its normal companion, creating an accretion disk around the compact star. As before, we have a central object surrounded by a flattened disk of gas. The high-velocity gas observed by Margon and his co-workers comes from two jets of gas separated by 180°. The compact object probably ejects the gas, while the accretion disk focuses the flow into jets. A more recent discovery adds to SS 433's peculiarity. A team lead by Richard Lamb of Iowa State University has found evidence that material in its plasma jets undergoes thermonuclear fusion — a tremendous surprise. Their finding may help explain the system's occasional flares.

A less spectacular but far more common example of mass loss occurs in evolved solar-type stars. Near the end of their lives, low-mass stars go through a phase that is accompanied by dramatic episodes of mass loss. For example, the Sun will swell and cool when it runs out of hydrogen in its core, becoming a red giant. Pulsations and small outbursts mark this stage of a star's life, and these events will eject matter from the Sun's outer layers. Eventually, the gaseous ejecta glow when the central core shrinks to become a hot white dwarf. (These stars produce ultraviolet radiation that ionize and heat the surrounding gas.)

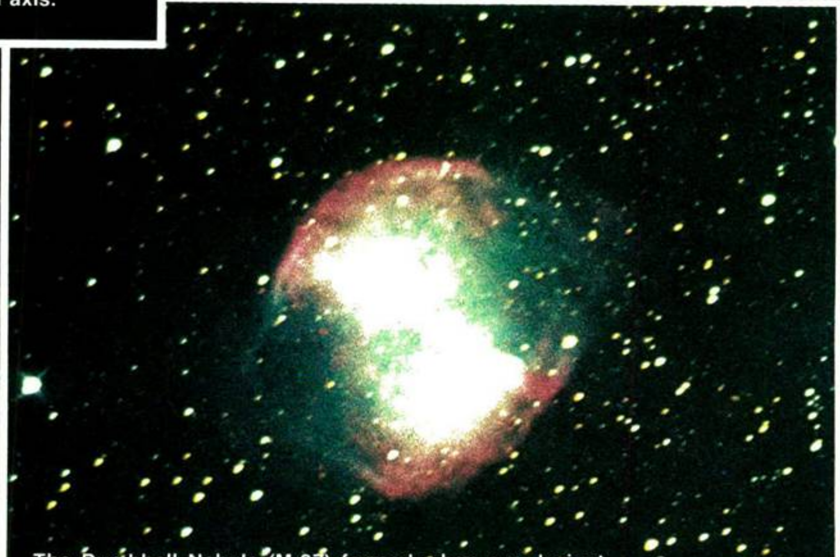


Two oppositely directed jets of fast-moving gas emerge from the nucleus of radio galaxy 3C-449. The hot gas forms radio-emitting lobes on either side of the galaxy.

NRAO

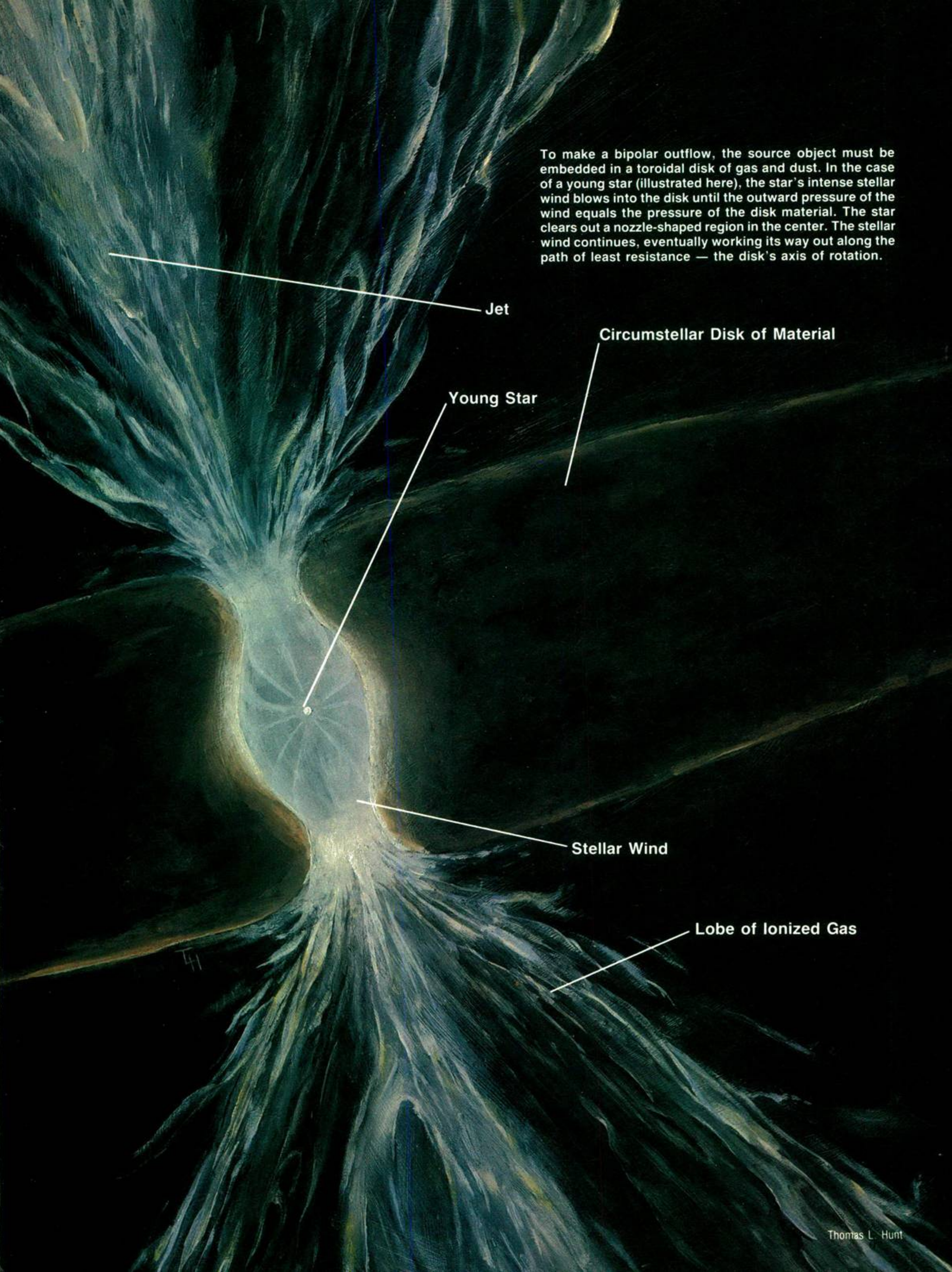


The neutron star in SS 433 pulls material from the outer layers of its stellar companion. The gas forms an accretion disk and spirals onto the neutron star, where explosive processes eject it along the star's rotational axis.



The Dumbbell Nebula (M-27) formed when a red giant sloughed off nearly a solar mass of material. Previously ejected matter probably restricts the nebula's expansion, accounting for its bipolar appearance.

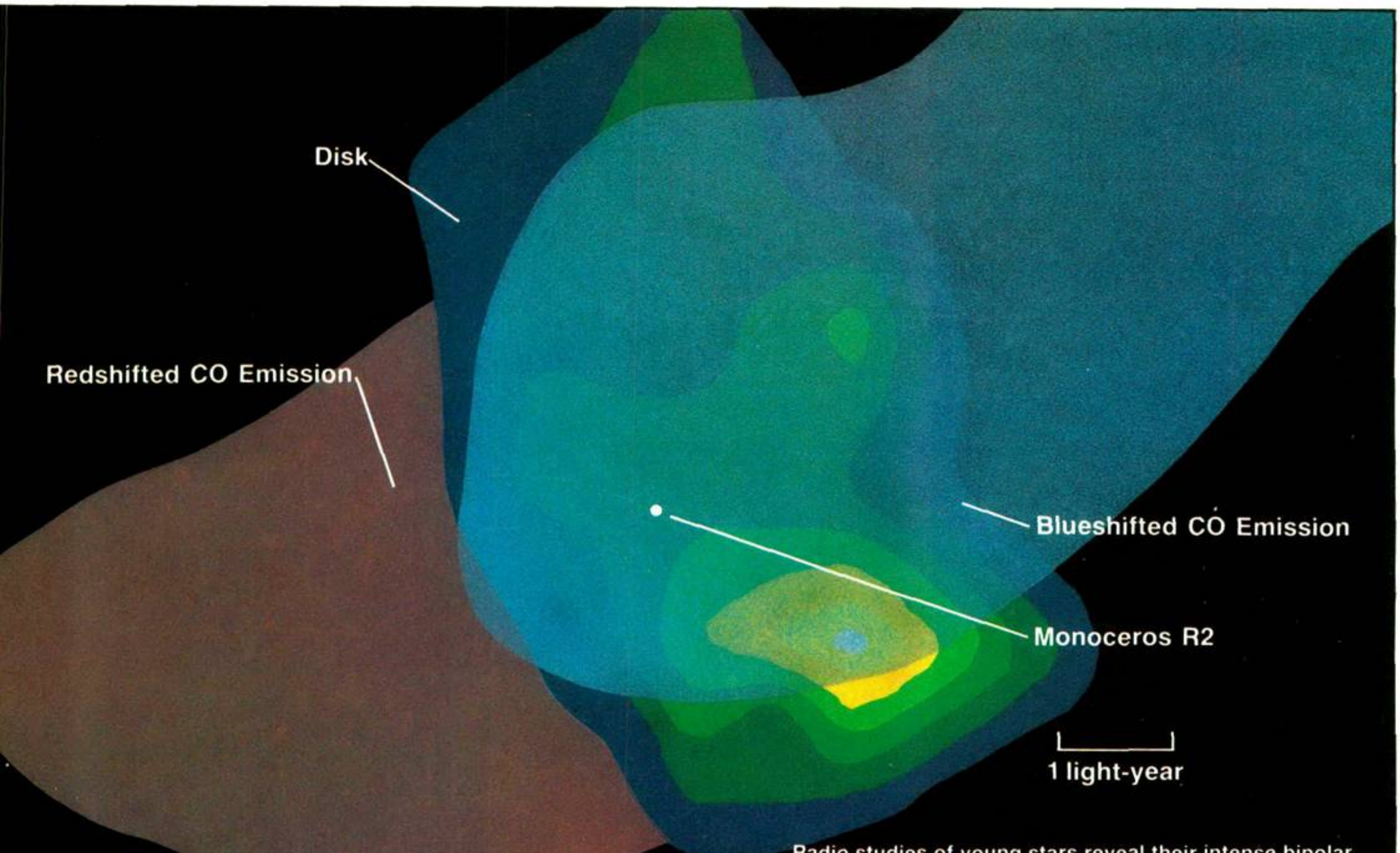
Ronald Royer



To make a bipolar outflow, the source object must be embedded in a toroidal disk of gas and dust. In the case of a young star (illustrated here), the star's intense stellar wind blows into the disk until the outward pressure of the wind equals the pressure of the disk material. The star clears out a nozzle-shaped region in the center. The stellar wind continues, eventually working its way out along the path of least resistance — the disk's axis of rotation.

Jet
Circumstellar Disk of Material
Young Star
Stellar Wind
Lobe of Ionized Gas

Thomas L. Hunt



Radio studies of young stars reveal their intense bipolar outflows. Radio emission from carbon monoxide (CO) molecules creates the best map of the outflow, while emission from ammonia best shows the circumstellar disk.

The result is a bright, expanding gaseous envelope with a hot central sun. These objects have received the rather confusing name of planetary nebulae, although they have nothing to do with planets.

The best-studied planetary nebulae are those with relatively large sizes; the gas seems to form an expanding ring or shell. There is, however, considerable evidence that younger, more compact planetary nebulae have bipolar structures. One of the best documented cases is that of NGC-6302, a gaseous object in Scorpius nicknamed the Bug Nebula. In the 1960s, Palomar astronomer Rudolph Minkowski found that its west lobe was, as a whole, receding from us, while the east lobe was approaching us — the signature of a bipolar outflow. Several astronomers have studied this and other compact planetary nebulae in detail, finding several cases with associated bipolar outflows, as well as evidence for powerful "winds" from their central stars. What causes the bipolar geometry? Nuria Calvet of Venezuela's Centro de Investigacion de Astronomica, and Universidad de Mexico astronomer Manuel Peimbert have speculated that in its early stages the red giant ejects a dense ring of gas. This slowly expanding ring later confines the fast wind from the central white dwarf and, as in the other objects we've discussed, precipitates the bipolar flow. Working with several astronomers at the Universidad Nacional Autonoma de Mexico and James Moran of the Smithsonian Astrophysical Observatory, I have found observational support for this hypothesis. At the center of NGC-6302, we found a ring of ionized gas lying in a plane perpendicular to that of the expanding nebula.

Bipolar outflows accompany objects large and small, old and new. Could it be that we are dealing with a common mechanism? To some extent, all objects have angular momentum and are permeated by magnetic fields; either of these can create an axis of symmetry. During the collapse of an extended cloud, for example, both rotation and magnetic fields will inhibit contraction in the plane perpendicular to the axis of symmetry, forcing the cloud into a pancake shape; a central object will probably condense in the center of the configuration. This evolutionary scheme is supposed to describe the formation of our planetary system. If the central object starts losing mass, the outflow will be stopped in the plane of the surrounding disk-shaped nebula, but will escape out the rotational or magnetic poles, thus creating twin jets of gas.

In the case of planetary nebulae, you might expect that a rapidly rotating star will eject a ring of gas centered on its equator, the portion of the star with the highest rotational velocity. Much later, when a hot white dwarf starts blowing its brisk stellar wind, the old ring of material could force the flow into a bipolar configuration.

Searching for a single explanation that will work over such vast ranges of size and energy could prove misleading and dangerous. Consider the following analogy. Stars and water drops are, to a first approximation, spherical. A star is spherical because of the gravitational attraction of its constituent matter. From this, one could conclude — erroneously — that the same force causes spherical water drops, whereas surface tension is really the more important mechanism. Nevertheless, despite reservations, some astronomers have speculated that these cosmic jets, both stellar and galactic, result from one basic mechanism — namely, a confining ring or disk of material around the source of the outflow. While this is a bold supposition, it may prove fundamental to our understanding of mass loss phenomena in the universe.

Luis Rodriguez is the director of the Instituto de Astronomia of the Universidad Nacional Autonoma de Mexico.

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ANNOUNCEMENT — The Yuma Astronomy Club now meets on the first Tuesday of every month at the Yuma City-County Library at 7:00 p.m. All skywatchers are welcome to join and make observations under clear Arizona skies. For information, write to: 875 W. 21 St., Yuma, AZ 85364; or phone Gilbert Luge at (602) 726-7423.

ANNOUNCEMENT — The Waterloo Amateur Astronomy Society has available astronomy programs for the Timex-Sinclair 1000 (ZX-81) and Atari computers. Includes Planet Finder and useful programs. New members welcome. Contact W.A.A.S., 25 Bridgeport Rd. East, Waterloo, Ontario, Canada N2J 2J4.

ANNOUNCEMENT — There will be a special full-day session on the teaching of astronomy (for junior high school, high school, and introductory classes in college) during the 96th annual scientific meeting of the Astronomical Society of the Pacific, July 7 through 13, 1984, University of California, Santa Cruz. Short contributed papers on teaching techniques, innovations, and resources are invited, as well as demonstrations of computer programs for teaching astronomy. Contact Summer Meeting, A.S.P., 1290 24th Ave., San Francisco, CA 94122. Phone (415) 661-8660.

ANNOUNCEMENT — The second annual Conference on Private Space Research and Exploration will be held on the weekend of May 26-27 at the Hayden Planetarium in New York City. The conference will be sponsored by the Independent Space Research Group and the Independent Space Projects Committee. Contact I.S.R.G. at P.O. Box 1246, Troy, NY 12180.

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ANNOUNCEMENT — The Astronomical Society of Ventura County, California, meets on the third Friday of the month at El Descanso Elementary School, Camarillo, California, at 7:30 p.m. The public is cordially invited. Contact Dave Holland, (805) 492-5059 or Dennis Leatart, (805) 983-7598.

ANNOUNCEMENT — The North Jersey Astronomical Group meets on the second Wednesday of each month at the Nature Center, Rifle Camp Park, West Paterson, New Jersey. For Information send SASE to N.J.A.G., P.O. Box 4021, Allwood Station, Clifton, NJ 07012.

ANNOUNCEMENT — The Astronomical Society of Long Island invites you to join us at our Wednesday meetings at C.W. Post College in Greenvale. Activities include weekly lectures, star parties, and telescope projects. Contact Jim Duffy, (516) 231-3191.

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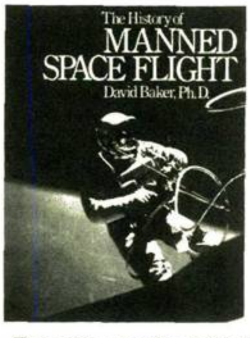

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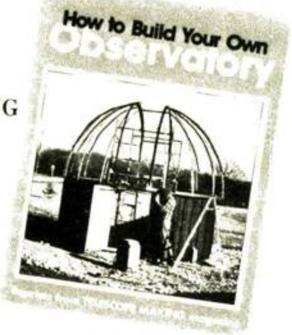

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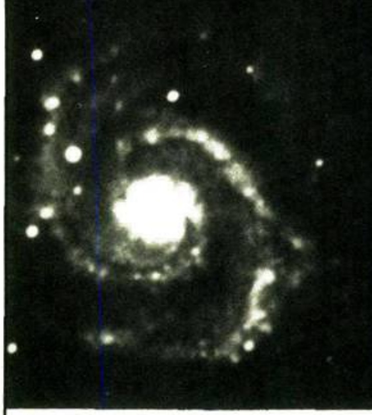

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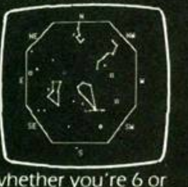

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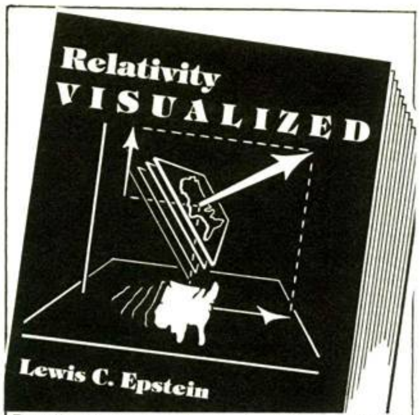

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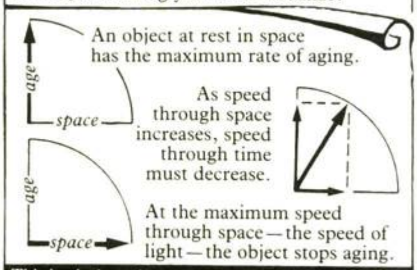

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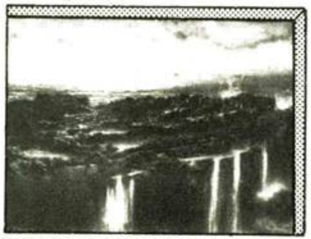

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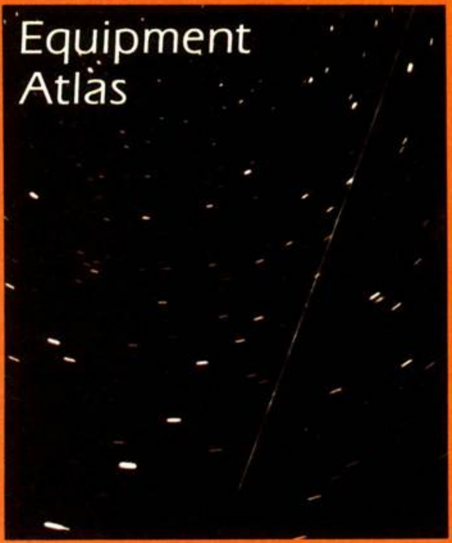
by
Larry C. Sessions

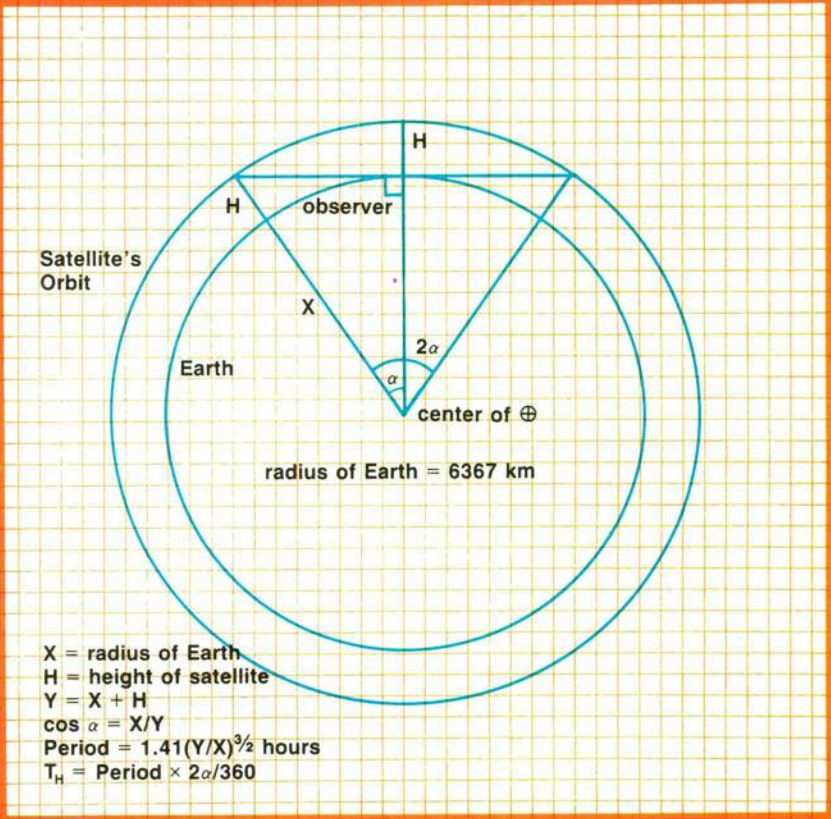


At star parties high in the Colorado mountains, I can usually count on three things happening every time: someone peering into the eyepiece will say, "Wow! Saturn really does have rings!", someone will spot a man-made satellite traversing the sky, and someone else will become preposterously excited and inquire about the "UFO." Indeed, since Sputnik blasted off in 1957, thousands of manmade satellites have rocketed into orbit — and out of about 5000 trackable objects now in orbit around Earth, a small percentage become visible as tiny moving "stars" during any given clear night. A few of these are spacecraft, but most are orbital debris such as burned-out rocket stages.

Most backyard astronomers occasionally see a satellite, but a small contingent of observers contributes data by regularly viewing satellites, and computing their times of passage to within seconds and their positions to within minutes of arc. This is difficult, because in the United States, satellite predictions are not published; it is easy to observe a satellite, but difficult to identify it. Observers who obtain predictions can help maintain a "fix" on certain satellites' positions and can also contribute to understanding the atmosphere's density, the solar wind, variations in Earth's gravitational field, and the exact shape of our planet — all by spotting satellites.

Before diving into observing techniques, let's digest a few basic facts about satellites. All satellites are gravitationally bound to their parent body (Earth, for instance) and follow elliptical or circular trajectories around them; their motion is such that for every foot they fall toward the parent body, that body moves out from under them an equal distance. This causes the satellites to maintain motion and constantly fall *around* their primaries, not *into* them. Factors such as atmospheric resistance at low altitudes and the pressure of the solar wind, affect orbits, but their influence is minimal.

A satellite's period — the time required for one orbit — varies with height. It is



X = radius of Earth
H = height of satellite
$Y = X + H$
$\cos \alpha = X/Y$
Period $= 1.41(Y/X)^{3/2}$ hours
T_H = Period $\times 2\alpha/360$

By using simple trigonometry, observers can calculate satellite facts such as height above Earth, periods, and transit times. Diagrams by Larry C. Sessions.

H	P	T_H
200 km	88.6 min	7.0 min
300	90.7	8.7
400	92.7	10.2
500	94.8	11.6
600	96.8	12.9
700	98.9	14.1
800	101.0	15.4
900	103.2	16.5
1000	105.3	17.7
1100	107.4	18.8
1200	109.6	19.9
1300	111.8	21.0
1400	114.0	22.1
1500	116.2	23.2
1600	118.4	24.3
1700	120.7	25.4

This table shows typical periods and transit times for satellites with circular orbits of various heights, assuming that the satellite passes overhead at the observer's location. H = satellite's height above Earth's surface in kilometers; P = satellite's period in minutes; T_H = maximum time satellite stays above horizon.

relatively short for low-altitude satellites and becomes progressively longer with high-altitude orbits. This holds true even for very elliptical orbits, as long as you consider the orbit's mean radius. Thus an elliptical orbit with a mean radius of 1400 kilometers above the Earth's surface has the same period as a circular orbit of the same radius.

If a satellite has a circular, west-to-east orbit at a radius of 35,900 km above the center of the Earth, its period exactly matches Earth's rotational period of about 24 hours. Such an orbit is called geosynchronous, and is rather difficult to achieve. A satellite in geosynchronous orbit appears to be stationary with respect to Earth: although Earth turns, the satellite paces along and keeps floating high above the same point on the ground.

But Earth's rotation greatly affects the positions of satellites in other types of orbits. Consider an object in a circular orbit with a period of an hour and a half. For simplicity, we'll assume that the orbit is inclined 90° to the equator — a "polar" orbit, in which the satellite passes directly over the North and South Poles. Earth rotates at a rate of 15° per hour, so it rotates 22.5° in the space of an hour and a half. Viewed from Earth's center, our satellite would pass 22.5° westward during its first orbit. But because we observe from the surface of the Earth, nearly 6600 km from its center, the satellite will *not* appear 22.5° west of its last orbit — except for near the poles, it will displace much more than 22.5°, and may well not be visible the second time around.

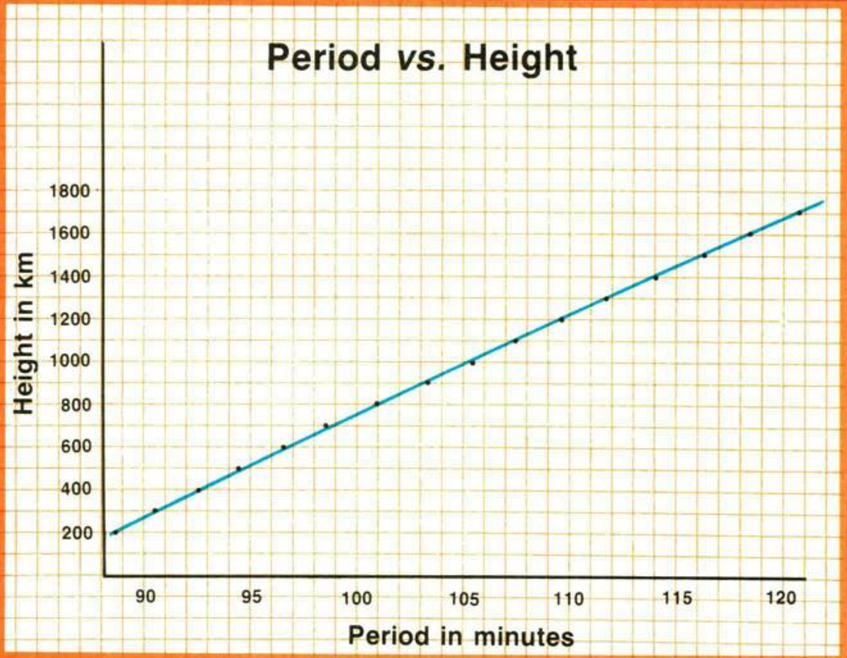
But not to worry — we have a convenient set of geographical coordinates for Earth's surface that can help you to predict where a satellite is headed. Lines of longitude allow us to say that if our polar-orbit satellite passes directly overhead in one location, it will pass directly overhead a spot 22.5° west in longitude on the next pass. Suppose the satellite passes directly over Milwaukee, at 88° west longitude, at 1 hour UT. At 2.5 hours UT it has completed one orbit, passing 22.5° west of Milwaukee and appearing overhead at 110.5° west longitude, just south of Yellowstone National Park. Since the satellite is less than 300 km above Earth's surface, it is below Milwaukee's horizon as it passes overhead at Yellowstone. Shortly after its eighth orbit it passes over Milwaukee moving in the opposite direction (8 x 22.5° = 180°), but this occurs during the daytime. The satellite again passes directly over in Milwaukee 16 orbits, or 24 hours, later.

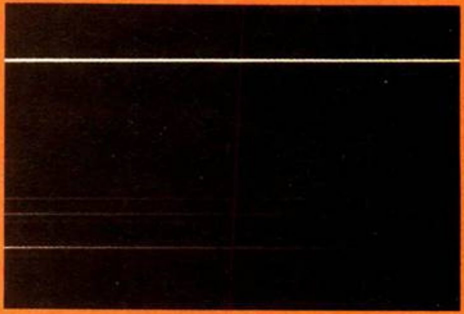
The situation becomes considerably more complicated when we consider satellites with other types of orbits. Inclined to the equator by 90°, a satellite passes over all latitudes; but if inclined, say, 45°, it only passes over between areas 45° north and 45° south latitude. It may occasionally pass through the zenith at Milwaukee (latitude 43° north), but *never* directly overhead at Winnipeg (latitude 50° north). Additionally, satellites in non-polar orbits are affected by precession, which slowly modifies their tracks and influences their visibility.

Let's say you go out under the stars and spot a satellite passing through the evening sky. What can you find out about it? To determine anything, you must observe the satellite on two separate passes. Suppose you're at the equator, and the satellite has a circular orbit. About an hour after sunset, you notice a faint object moving south to north in the eastern sky. The satellite reaches an altitude of about 60° above the eastern horizon. Since you can't accurately measure its angular velocity, you must make some educated guesses about its period, thus determining roughly where and when to look for it on the next pass. Since you know that most readily observed satellites — those you can see easily without optical aid — have periods between one and a half and two hours, you plan to search for the satellite again starting in just less than 90 minutes.

About an hour and twenty minutes later you begin searching the sky, but because you don't have complete information, you really don't know just where to look. Because the satellite reached its maximum elevation due east, it appeared to be a polar satellite, one with a 90° inclination to the equator. Therefore you might expect it to appear in the south and move northward next time, and because Earth is rotating, the satellite will appear to be west of its original pass. You still don't know how high it will appear above the horizon, so you scan the western skies from zenith to horizon.

Minutes pass. Long minutes. The mosquitoes attack, fully intending to drain you dry by morning. More minutes pass. It's getting colder. The mosquitoes get worse, but the sudden appearance of a nice meteor or two makes it worthwhile. Still no satellite. Finally, just as you're ready to pack it in, you spot it. Or at least you think it's the same satellite. It is fainter than you expected and rises less than 20° high in the western sky. But it does appear to be in a polar orbit, so you check your watch to see that the satellite has a period of two hours.

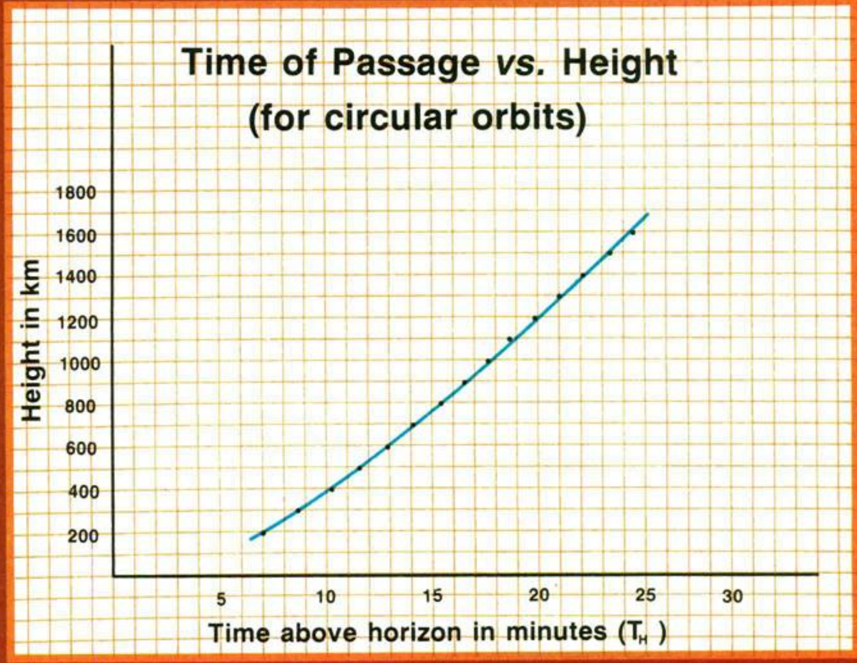




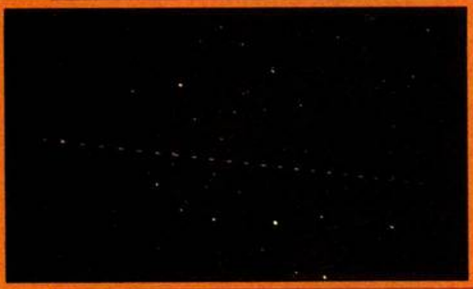
Left: The period *vs.* height relationship for satellite orbits. Above: A geosynchronous satellite photographed by Al Lilge with a 12.5-inch f/8 Ritchey-Chretien telescope and a 15-minute exposure on 2415 emulsion. During the exposure, the satellite moved only 20 seconds of arc.

It might be nice to confirm your observation by checking the satellite on its third orbit, but alas, by then the satellite will arrive too far to the west to be visible. But since the satellite has a period of two hours, after exactly 12 orbits, or 24 hours, it will repeat the passages you've just witnessed. So the next night you go out at the same time, endure the mosquitoes again, and sure enough, there it is!

You may notice that the satellite seems slightly farther west with each succeeding night. As calculated from Earth's center, it will move about one degree farther west each night; this is because Earth rotates once in 23 hours 56 minutes. Satellites in polar orbits maintain a fixed orbital plane with reference to the stars, not the Sun or Earth. But the satellite takes 24 hours to complete 12 orbits, and in the remaining four minutes the Earth has turned an extra degree; hence the satellite passes one degree farther to the west. If the period doesn't divide 24 hours into integers, then the satellite passes overhead at different times on different nights. And when it does pass over, a path change occurs due to the "slack time."



Right: The transit time *vs.* height relationship for satellite orbits. Below: Paul Maley photographed the Cosmos 116 rocket as it swept across Ursa Major in this 22-second exposure. As the satellite tumbled, it flashed on and off once a second.



Now you can predict when and where to look for this satellite in the future. But it will prove difficult to identify the satellite — something you would need to know to contribute scientifically useful data to satellite watchers. It is best, then, to concentrate on simply predicting satellite passes and not worry about whether they represent American communications relays or Soviet spy satellites.

Simple mathematics will tell you that an object at a height of 400 km is above the horizon anywhere on the Earth's surface for a radius of approximately 2200 km from the point directly below the object. At a height of 800 km, a satellite is above the horizon anywhere within a radius of about 3,038 km. It isn't necessarily easily visible, however: as orbits get higher, satellites appear fainter. The relationship is not linear, though: the satellite's albedo (reflectivity), surface area, and angle toward Earth and Sun all affect its apparent magnitude as it zips across the sky.

The position of Earth's shadow is also a factor in a satellite's visibility. The shadow height varies throughout the night, being greatest at local midnight, when its maximum height is to the south for northern hemisphere observers and to the north for southern hemisphere observers. The shadow is highest at positions opposite the Sun; thus, after sunset it is highest in the east, with the reverse true shortly before sunrise. The exact position depends on the season — in the northern hemisphere the Sun sets in the northwest during summer, so the shadow is the southeast, and so on. Shadow height also varies with seasons, increasing during winter and decreasing during summer. Generally, the easiest times for observing are usually the couple of hours after sunset (looking to the west) or before sunrise (looking to the east).

The bright satellites are usually in fairly low orbits and move across the sky rapidly. You must be looking at just the right time or you'll miss them. Begin your search for a particular satellite 15 minutes before your predicted time of passage — this will ensure that you'll spot the satellite and will sharpen your ability to predict passages. If at some point you can't find a particular satellite, don't be too discouraged. Because of the various factors that affect orbits, many satellites go through periods of several weeks when they remain conspicuous, and then enter periods of as much as several months when they grow dimmer.

Satellite watching is a growing subinterest in astronomy. Some amateur astronomy organizations, particularly the British Astronomical Association, foster the art of satellite observing; if you're serious about it, they may supply you with predictions or help you identify the satellites you've observed. Their address is: B.A.A., Burlington House, Piccadilly, London W1V ONL, England. In addition, your local planetarium or university astronomy department may be able to obtain the current copy of *Satellite Situation Report*, a periodical published by NASA's Goddard Space Flight Center in Greenbelt, Maryland. This booklet lists hundreds of satellites with their orbital periods, inclinations, and other data. Once you've done some observing, it may help you to identify satellites if you have good data from your observations to compare with periods and inclinations from the NASA booklet.

The next time you go out under the stars and see a light moving across the sky, perhaps you'll record its brightness, direction of travel, and time of passage. If you're lucky and think about what it's doing, you'll return on another night and greet your far-off man-made friend once again. Once you do this, you'll be hooked on a curious, enjoyable facet of observational astronomy.

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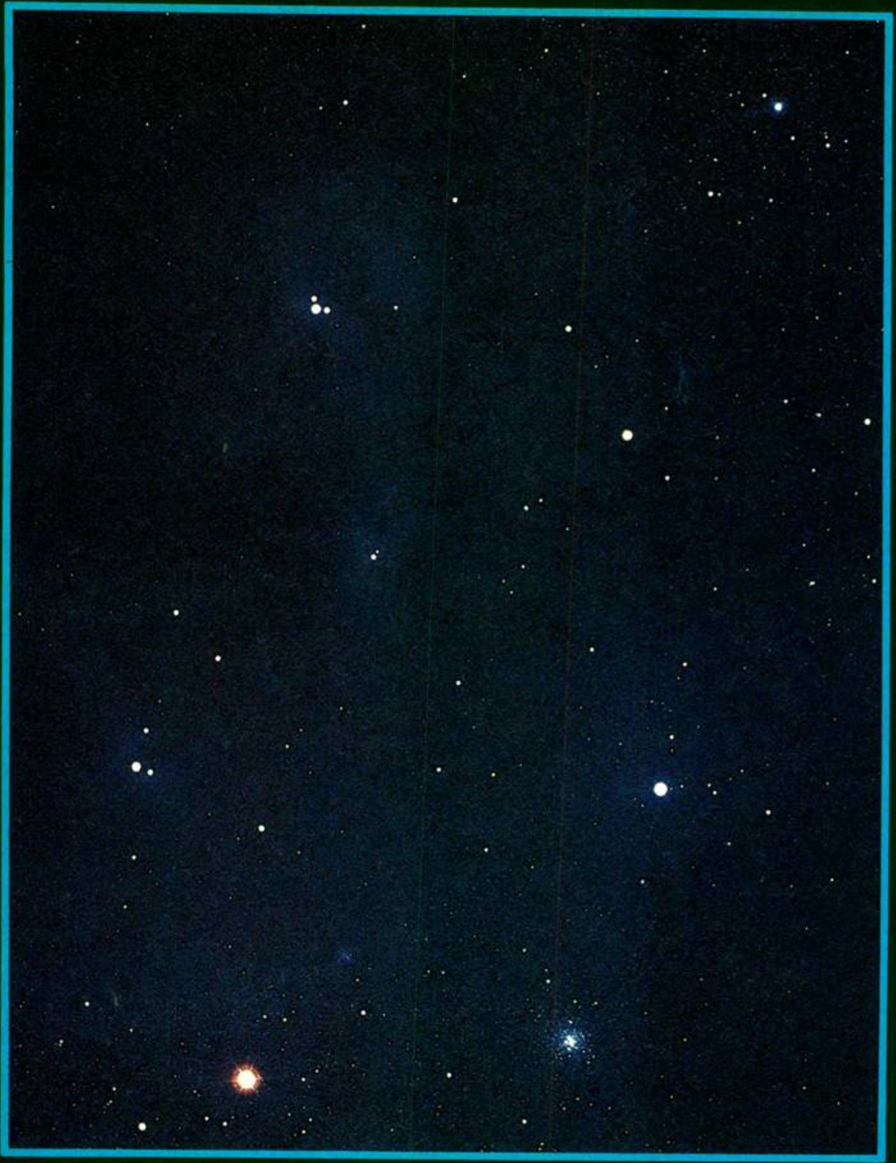
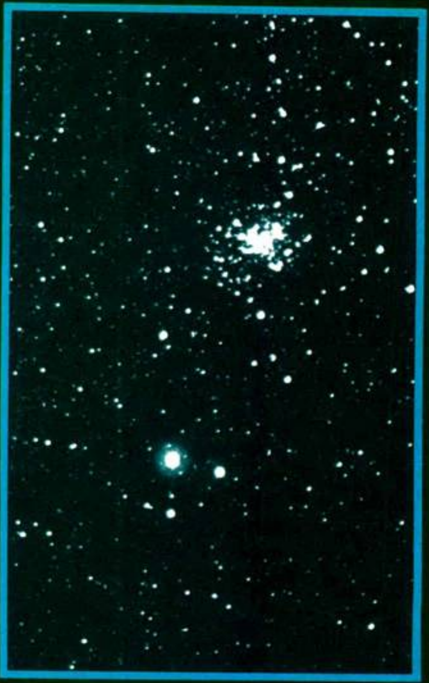
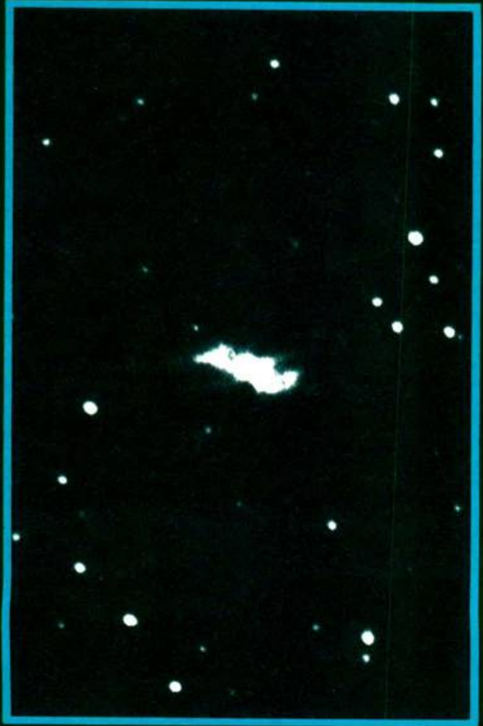




Left: The region of Antares contains abundant star clusters and wispy nebulosity. In Bill Iburg's photo are Antares and globulars M-4 and NGC-6144 at bottom, globular M-80 at upper right, and a haze of reflection nebulosity covering the field. Top right: Jack Marling's photo of the large open star cluster NGC-6231 shows it as a clump of uniformly bright stars. Bottom left: NGC-6302, the Bug Nebula, is a curious bipolar object in central Scorpius. Photo by Martin C. Germano. Bottom right: David Healy's photo of the huge clusters M-6 and M-7 shows a section of sky strewn with stars.

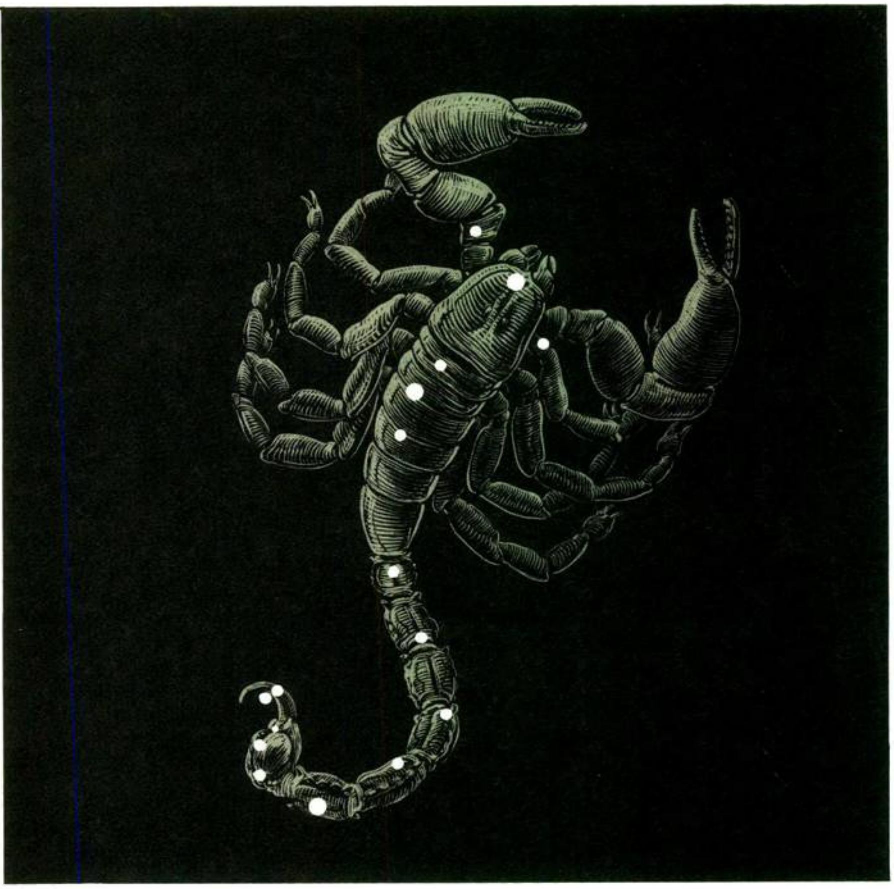


The Backyard Astronomer

Scorpius

Sco

Scorpii



Keith Ward

Scorpius the Scorpion, one of the richest areas of the entire sky, holds a multitude of bright and impressive stars, star clusters, wispy nebulae and pulsating variables. This is not surprising, since looking toward Scorpius affords a view in the direction of our Galaxy's center — the nucleus of the Milky Way. Bounded by the bright stars of Sagittarius and Centaurus, Scorpius offers binocular fields peppered with tiny stars and telescopic views of most types of deep-sky objects.

The brightest, most obvious object in the constellation is the open cluster **M-7** (NGC-6475), a giant group of 130 stars, more than half of which are brighter than 10th magnitude. With a combined magnitude of about 3.3, the stars of M-7 form one of the brightest of all open star clusters, noticeable to the naked eye as a fuzzy patch even under suburban skies. It lies about 4° northeast of 1.6 magnitude Shaula (Lambda [λ] Sco). M-7 is mentioned in Ptolemy's star catalog and is cited as a nebulous patch in the 16th century Latin translation of the *Almagest*. It is so bright and large that the best views often come in finder telescopes with magnifications of around 10x. As M-7 covers an area 50′ across, any telescope must operate at low powers to contain all of it. The faint and distant globular cluster NGC-6453 lies in the same field as M-7 and appears like an 11th magnitude spot of grainy nebulosity only 1′ across.

The brightest individual member of M-7 shines at magnitude 5.6 and is of spectral type G8; most of the other bright members are type A and B stars. The cluster lies some 273 parsecs distant. Computations show it to be approximately 260 million years old — considerably older than young clusters like the Pleiades, but far younger than such aged galactic objects as the globular clusters.

Some 3.5° northwest of the great M-7 lies another of Scorpius' bright clusters, **M-6** (NGC-6405). Although it is a naked-eye object, the group's telescopic "discovery," made in 1746, is credited to Philippe Loys de Cheseaux. It is sometimes called the Butterfly Cluster because of its arrangement of winglike strings of stars of similar brightness. M-6 contains 132 stars in an area 26′ across, and glows at magnitude 4.6 — again, use low powers with telescopes and scrutinize the group with binoculars if you have them. The brightest star in M-6, **BM Scorpii**, is an unusual long-period variable displaying an orange tint. (BM Sco's spectral class varies between K0 and K3.) It fluctuates between magnitudes 6.0 and 8.1 in a decidedly irregular manner: as you observe M-6, look for the bright orange star in the northeast section of the cluster and, once every few weeks or months, compare its brightness to stars surrounding it. BM Sco's period is roughly 850 days; in time you'll create a record of the star's behavior and gain experience in estimating subtle differences in stellar brightness. Nearly 450 parsecs distant, M-6 lies nearly twice as far away as its brilliant neighbor M-7.

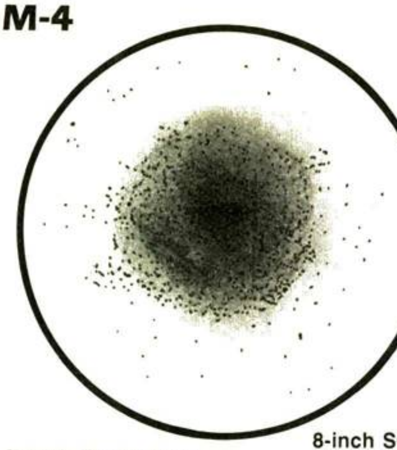
South of M-7, just 4.5′ east of the magnitude 3.5 star G Scorpii, lies the little globular cluster **NGC-6441**. This eighth-magnitude object measures just 3′ across and is composed of multitudes of 17th magnitude and fainter stars: it has a high surface brightness, but is partially obliterated by the bright star practically lying on top of it. After you locate the fuzzy patch of grey light, switch to moderately high powers to increase contrast between sky background and globular, and try to keep the star just outside the scope's field of view. Although it isn't a highly impressive object, 6441 is always easy to find.

A slightly bigger and brighter globular lies in a more barren region at the base of the Scorpion's stinger — **NGC-6388**, a seventh-magnitude group offering a fine sight for small telescopes. This cluster is marginally larger than 6441; it appears as a grainy mottled disk at high power in a 5-inch reflector. Large telescopes, in the 12-inch-and-up class, fail to resolve 6338, whose tiny 17th magnitude members remain hopelessly merged.

Moving northeastward up the Scorpion's body, we find the dazzling open star cluster **NGC-6231**. This assemblage lies half a degree north of the bright star Zeta (ζ) Scorpii, and includes some 120 stars in its 15′ diameter. NGC-6231 glows at sixth magnitude, making it within naked-eye range. It contains a remarkably high number of intensely luminous O- and B-type supergiants — at fifth and sixth magnitude, they appear as bluish-white beacons in small telescopes. On a dark clear night, NGC-6231's brilliance in low power fields will startle you: it looks like luminescent buckshot, sprayed onto the velvet black

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

M-4



Sketch by David J. Eicher

8-inch SCT
70x

background of interstellar space. Were it as close as the Pleiades, it would cover the same amount of sky but outshine the Pleiads by a factor of 50!

Just northeast of NGC-6231 is the looser conglomeration of stars known as **H 12**. A stellar association containing at least 200 stars, H 12 is involved with the faint nebulosity IC 4628, which is invisible in small telescopes. The group is designated the I Scorpii Association; it indicates the course of one of the Milky Way's spiral arms, about 1700 parsecs distant, in the direction of the galactic center.

An unusual isolated object is the bipolar nebula **NGC-6302** (otherwise known as the Bug Nebula, due to its funny crab-like appendages). A mere 2′ x 1′ in extent, this slender streak of fuzz glows rather dimly. Its central illuminating star shows a B6-type spectrum and shines at 10th magnitude. The exact nature of 6302 is questionable, but its bipolar structure suggests a young planetary nebula whose parent star "burped" a ring of ionized gas and later drove off its outer envelope with fierce stellar winds.

One of the most beautiful regions of the sky surrounds **Antares**, Alpha (*α*) Scorpii. This area contains several globulars, fine double stars, and extensive wispy, low-surface-brightness reflection nebulosity. Antares itself is a ruddy M1 supergiant, of magnitude 0.9, and one of the easiest in which to detect color. ("Antares" in Greek means "Rival of Mars.") This aged star shows slight, erratic variations in brightness, and is about 600 million miles across, or about 700 times the size of the Sun. Since its density is exceedingly low, however, Antares is not supermassive — only about 10 or 15 times the mass of Sol. The great red giant has a tiny greenish companion star, about 3″ away at position angle 275° (1959); the little star's magnitude is 6.5, making it extremely difficult to spot in Antares' overpowering glare. It can nevertheless be glimpsed in a 6-inch reflector under good seeing conditions.

Near Antares are three fine globulars, one of which is exceptional. **M-4** (NGC-6121) is one of the most easily resolved such clusters in small scopes because of its large diameter of 23′ and loose, unconcentrated structure. On nights of fine transparency, a good 4-inch telescope at high power can resolve the entire face of the group into pinpoint multitudes of stars. Its combined magnitude is about 7.4, and its brightest individual stars about magnitude 11. Some of these stars appear to form a central "bar" cutting across M-4's central region, a feature distinct in most telescopes. This globe contains 10,000 known stars down to 19th magnitude, and undoubtedly many fainter ones. At a distance of 1.8 kiloparsecs, it is one of the closest globulars to the solar system. Forming a triangle with Antares and M-4, 1.5° northwest of Antares, is the globular **NGC-6144**. This group shines at 10th magnitude and spans 3′; it is visible as a smallish grainy nebulosity in 5-inch telescopes.

The globular cluster **M-80** (NGC-6093) is an eighth-magnitude object measuring 7′ across; it lies north of the M-4/6144 region and is a downright impressive disk of stellar images. Its constituent stars glow softly at 14th magnitude and fainter; observers with instruments of medium or large aperture can expect to resolve its outer periphery with high powers on nights of steady transparency. It contains the nova T Scorpii, which suddenly erupted from anonymity to seventh magnitude in 1860.

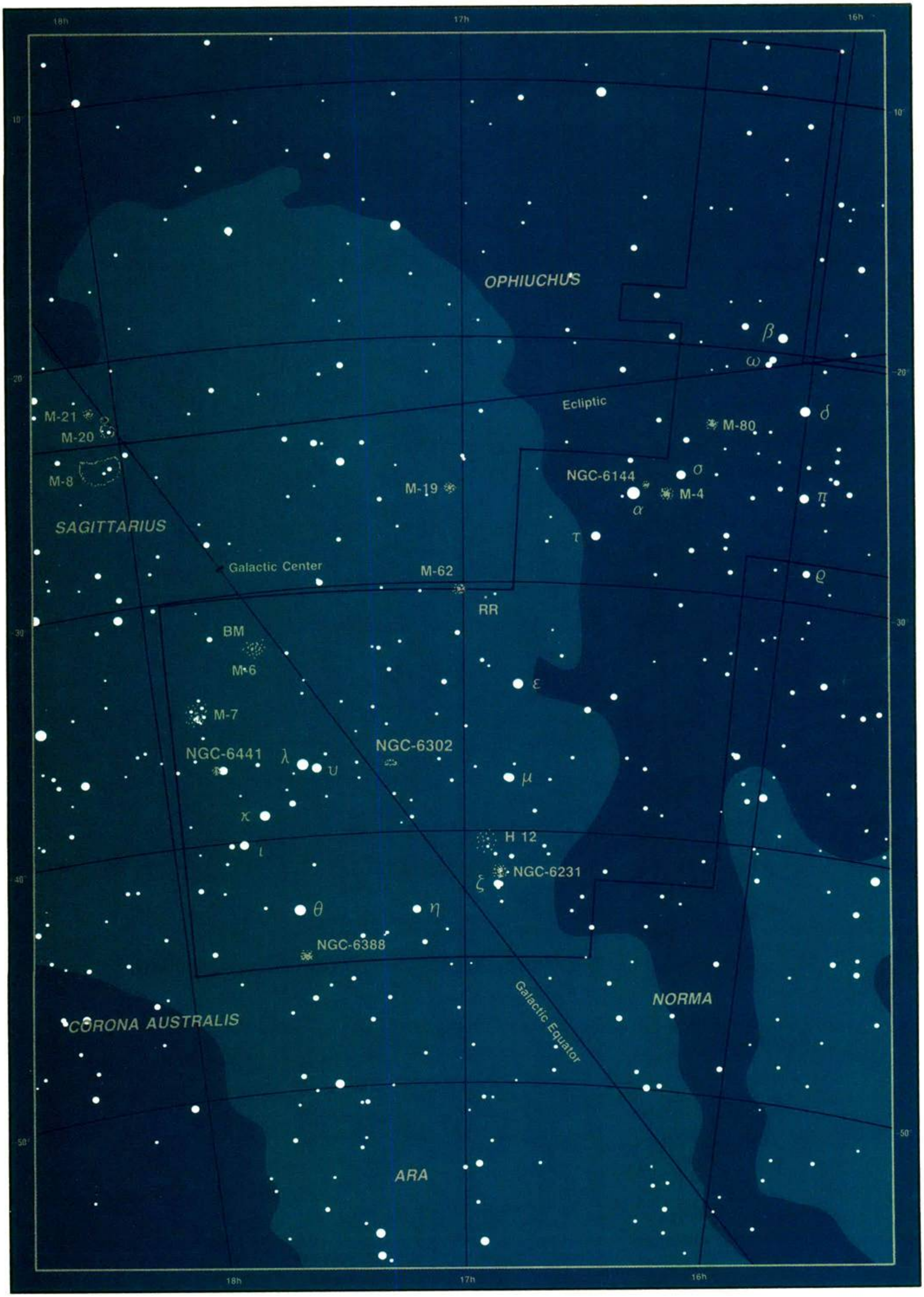
The fine double and multiple stars **Akrab** (Beta [*β*] Scorpii) and **Nu** (*ν*) **Scorpii** offer bright, colorful sights for small-telescope users. One of the most enticing bright doubles in the sky, Akrab is plainly visible in a 2-inch refractor. The individual components shine at magnitudes 2.6 and 4.9, and are separated by 13.7″ in p.a. 23° (1958); both are early-type bluish-white stars. The pair lies at a distance of just under 150 parsecs, making its luminosity about 2700 times that of the Sun. The Beta Sco system contains a fainter, more distant star that is a spectroscopic double, making Beta a quadruple star system. Nu Scorpii, which lies 1.5° east and slightly north of Beta, is an observable quadruple system. It consists of magnitude 4.0 and 6.2 stars separated by 41.4″ in p.a. 336° (1955); each star in this double is itself a double, resulting in a grand total of four.

Perhaps the finest variable star in Scorpius is **RR Scorpii**, a long-period variable ranging from magnitude 5.1 (naked-eye object) to magnitude 12.3 (just visible in small scopes) in a period of some 279 days. As with BM Sco, make a sketch and magnitude estimate of this star and its surrounding field every few weeks on a regular basis. You'll record a little bit of the star's "life history," documented about 600 years after the fact.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★	Mag.★
Beta (*β*)		★^{2}	16h 05.5m	−19°48′	2.6,4.9	13.7″		
Nu (*ν*)		★^{4}	16h 12.9m	−19°29′	4.0,6.2	1.2″		
					7.0,7.3	2.3″		
NGC-6093	M-80	●	16h 18.0m	−22°59′	8.4	5.1″		14...
NGC-6121	M-4	●	16h 23.7m	−26°31′	7.4	22.8′		11...
NGC-6144		●	16h 27.3m	−26°03′	10.0	3.2′		14...
Antares (*α*)		★^{2}	16h 29.5m	−26°26′	0.9,6.5	3.0″		
NGC-6231		⊙	16h 54.2m	−41°48′	6.0	15.0′	120	6....
H 12		⊙	16h 56.2m	−40°43′	8.5	40.0′	200	
RR		LPV	16h 56.6m	−30°35′	5.1↔12.3	279d		
NGC-6302		☐E	17h 13.9m	−37°06′	12.0	2′x1′		
NGC-6388		●	17h 36.3m	−44°45′	7.0	4.0′		17....
NGC-6405	M-6	⊙	17h 40.0m	−32°13′	4.6	26.0′	132	6....
BM		LPV	17h 40.9m	−32°13′	6.0↔8.1	850d		
NGC-6441		●	17h 50.2m	−37°03′	8.0	3.0′		17....
NGC-6475	M-7	⊙	17h 54.0m	−34°49′	3.3	50.0′	130	6....

N★ = number of stars, Mag.★ = magnitude range of cluster or magnitude of central star, (...) indicates many fainter.

★^{2}	*Double Star*
★^{4}	*Quadruple Star*
●	*Globular Cluster*
⊙	*Open Cluster*
LPV	*Long Period Variable*
☐E	*Emission Nebula*


18h
17h
16h
10°
20°
30°
40°
50°
OPHIUCHUS
β
ω
Ecliptic
δ
M-80
M-21
M-20
M-8
σ
NGC-6144
M-4
α
π
M-19
SAGITTARIUS
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Galactic Center
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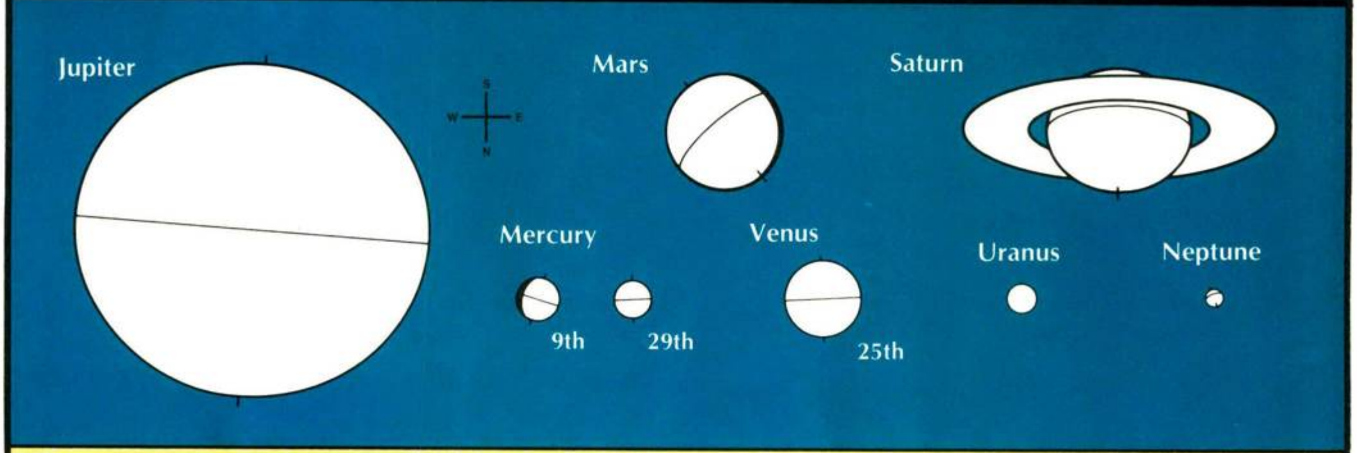
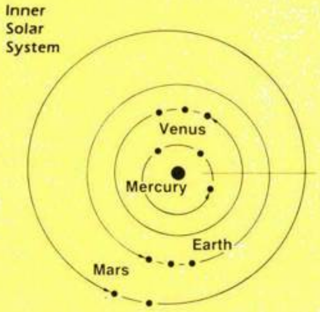
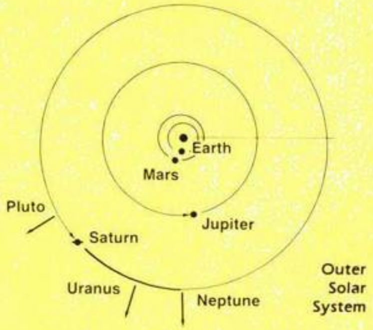
Planetary Data

June 1984


Jupiter
Mars
Saturn
S
W
E
N
Mercury
9th
29th
Venus
25th
Uranus
Neptune

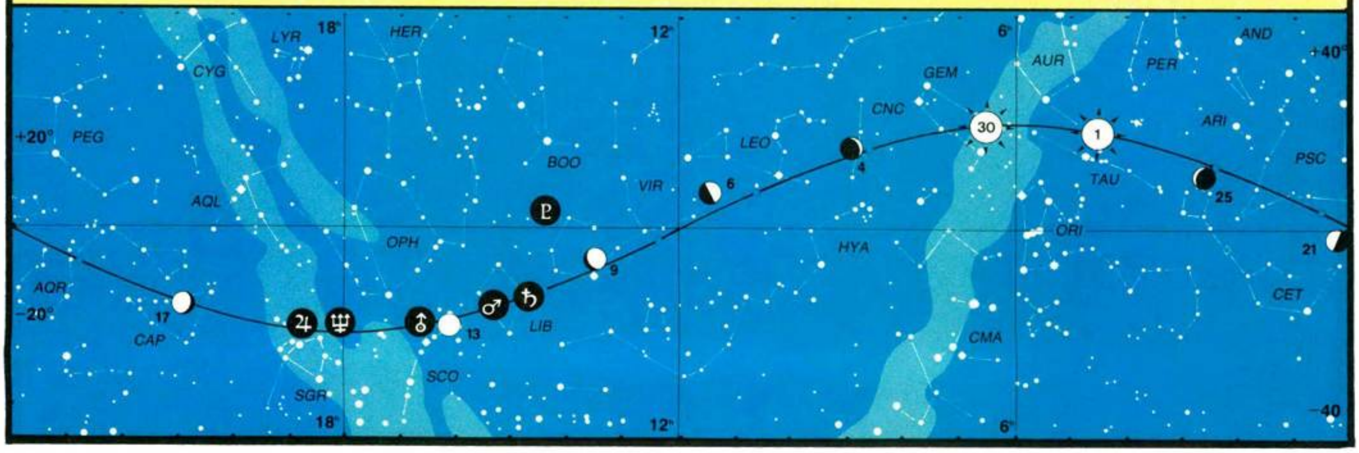
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.7	31.6′	—	1.01	—	—	70°41.6′	4h 37.3m	22°04.9′
		15	−26.7	31.5′	—	1.02	—	—	84°05.0′	5h 35.1m	23°19.1′
		30	−26.7	31.5′	—	1.02	—	—	98°23.7′	6h 37.5m	23°09.8′
Mercury	☿	1	−0.2	6.5″	62%	1.04	0.39	332°55.6′	48°33.0′	3h 09.5m	15°02.9′
		15	−1.4	5.3″	92%	1.27	0.32	41°34.0′	73°54.4′	4h 53.0m	22°20.6′
		30	−1.4	5.2″	95%	1.30	0.33	132°49.8′	106°05.4′	7h 13.9m	24°08.6′
Venus	♀	1	−3.9	9.7″	100%	1.73	0.72	60°55.9′	64°55.8′	4h 20.3m	21°04.7′
		15	−3.9	9.6″	100%	1.74	0.72	83°28.8′	83°21.1′	5h 34.0m	23°28.7′
		30	−3.9	9.7″	100%	1.74	0.72	107°44.6′	101°46.9′	6h 54.5m	23°35.2′
Mars	♂	15	−1.4	15.7″	95%	0.59	1.50	248°52.8′	225°17.4′	14h 36.5m	−16°57.6′
Jupiter	♃	15	−2.6	46.4″	100%	4.24	5.23	276°52.2′	275°41.8′	18h 44.0m	−22°57.5′
Saturn	♄	15	0.3	18.2″	100%	9.11	9.87	224°25.3′	219°14.8′	14h 35.8m	−12°35.9′
Uranus	⛢	15	5.5	3.9″	100%	18.03	19.02	251°43.4′	250°34.7′	16h 38.8m	−22°05.9′
Neptune	♆	15	7.9	2.3″	100%	29.25	30.26	270°00.7′	269°43.2′	18h 01.9m	−22°13.5′
Pluto	♇	15	13.7	0.1″	100%	29.25	29.82	211°08.6′	209°05.2′	14h 14.5m	4°44.6′


Inner Solar System
Venus
Mercury
Earth
Mars


Earth
Mars
Pluto
Jupiter
Saturn
Uranus
Neptune
Outer Solar System

Moon Data

First Quarter	June 6 at 16:42
Full Moon	June 13 at 14:42
Last Quarter	June 21 at 11:10
New Moon	June 29 at 3:18
First Quarter	July 5 at 21:04
Full Moon	July 13 at 2:20
Perigee: June 7 at 11:24	369,568 km.
Apogee: June 20 at 19:44	404,232 km.


LYR
18°
HER
12°
6°
AND
+40°
CYG
GEM
AUR
PER
+20°
PEG
CNC
30
1
ARI
LEO
BOO
4
VIR
6
TAU
PSC
25
AQL
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ORI
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HYA
21
9
AQR
−20°
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13
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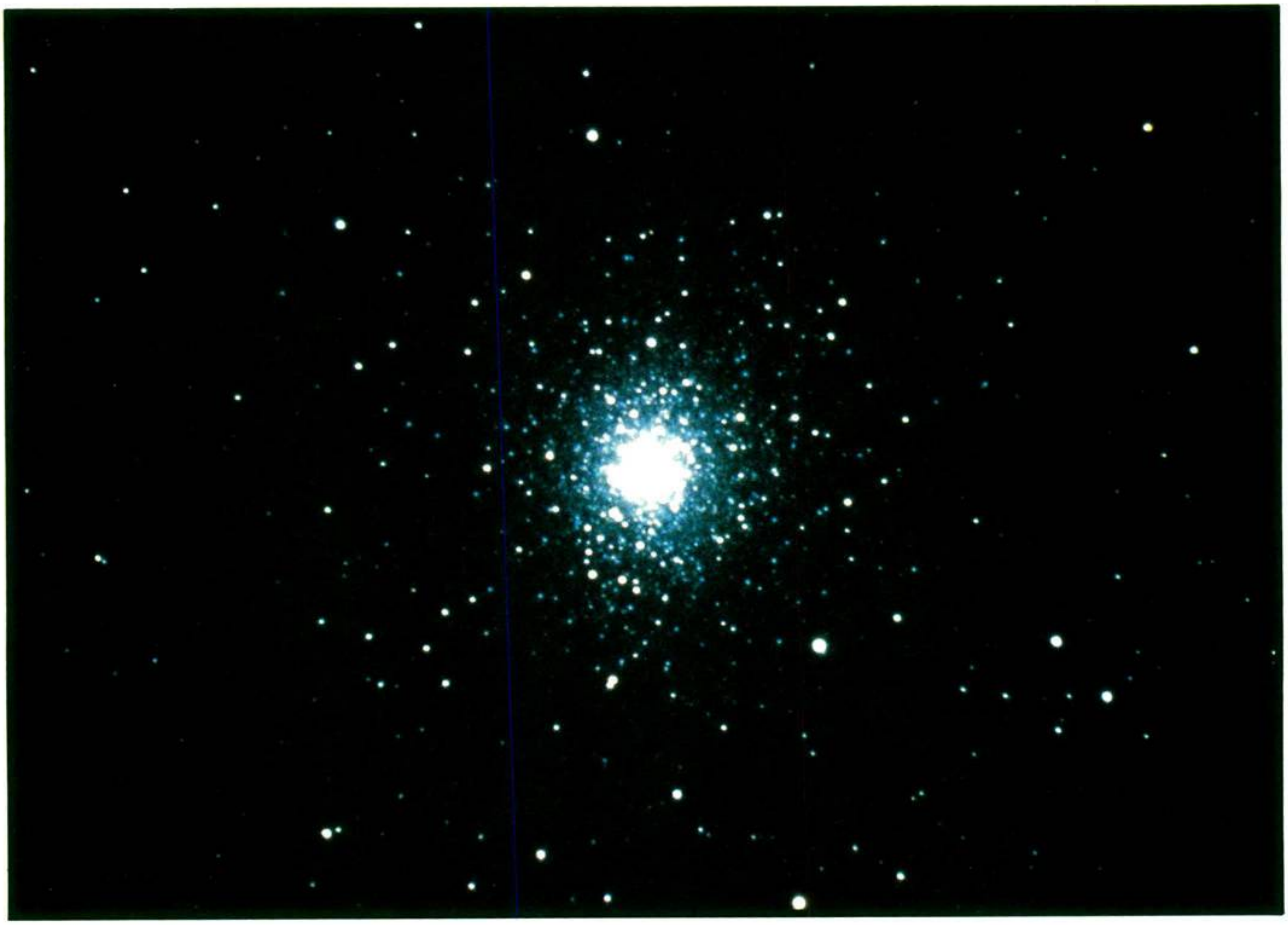


Bill Iburg photographed Hercules' *other* globular cluster, M-92, with a 14-inch SCT at f/5.5, 400-speed film, a cold camera, and a 20-minute exposure.

Mercury

Mercury passes superior conjunction on June 23rd; it will be out of view until late in July.

Venus

Venus is also out of sight; it passes superior conjunction on June 15th, and won't reappear until August.

Earth

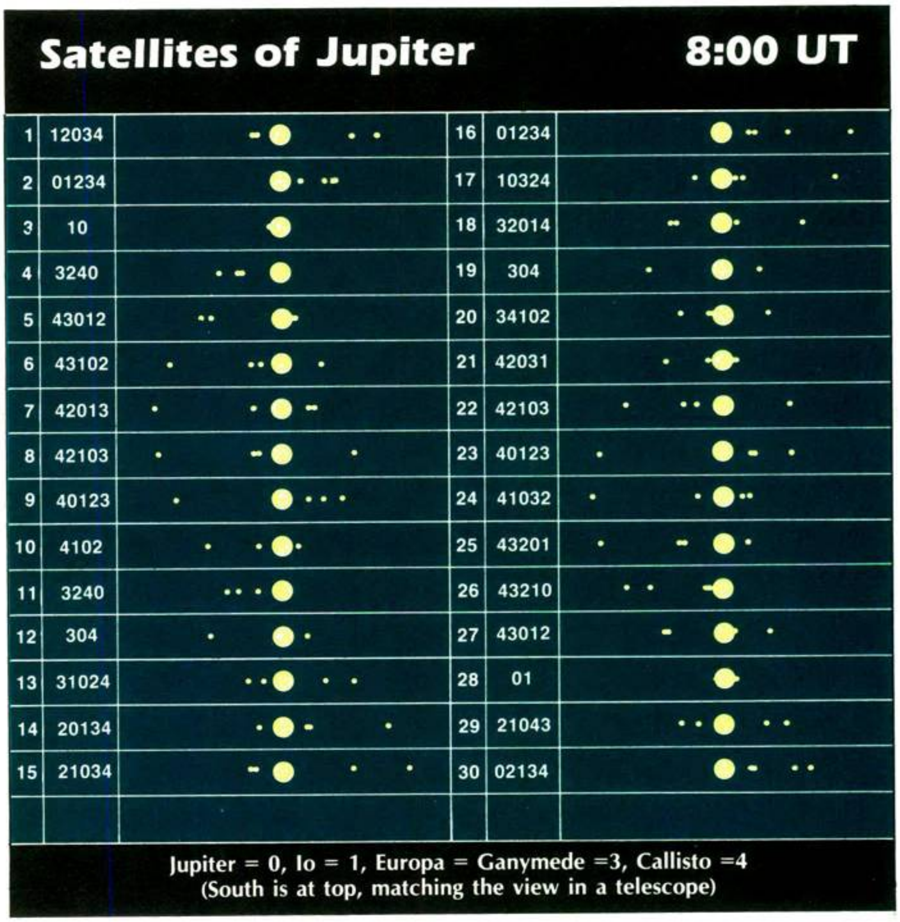
The summer solstice occurs at 5:02 UT on June 21st, when the Sun reaches its greatest northern declination.

Moon

On June 13th, the Moon will pass through the outer southern part of the Earth's penumbra between 10:01 UT and 15:09 UT. The event won't be visible from North America — and in any case the darkening is so slight (eclipse magnitude = 0.09) as to be undetectable.

Mars

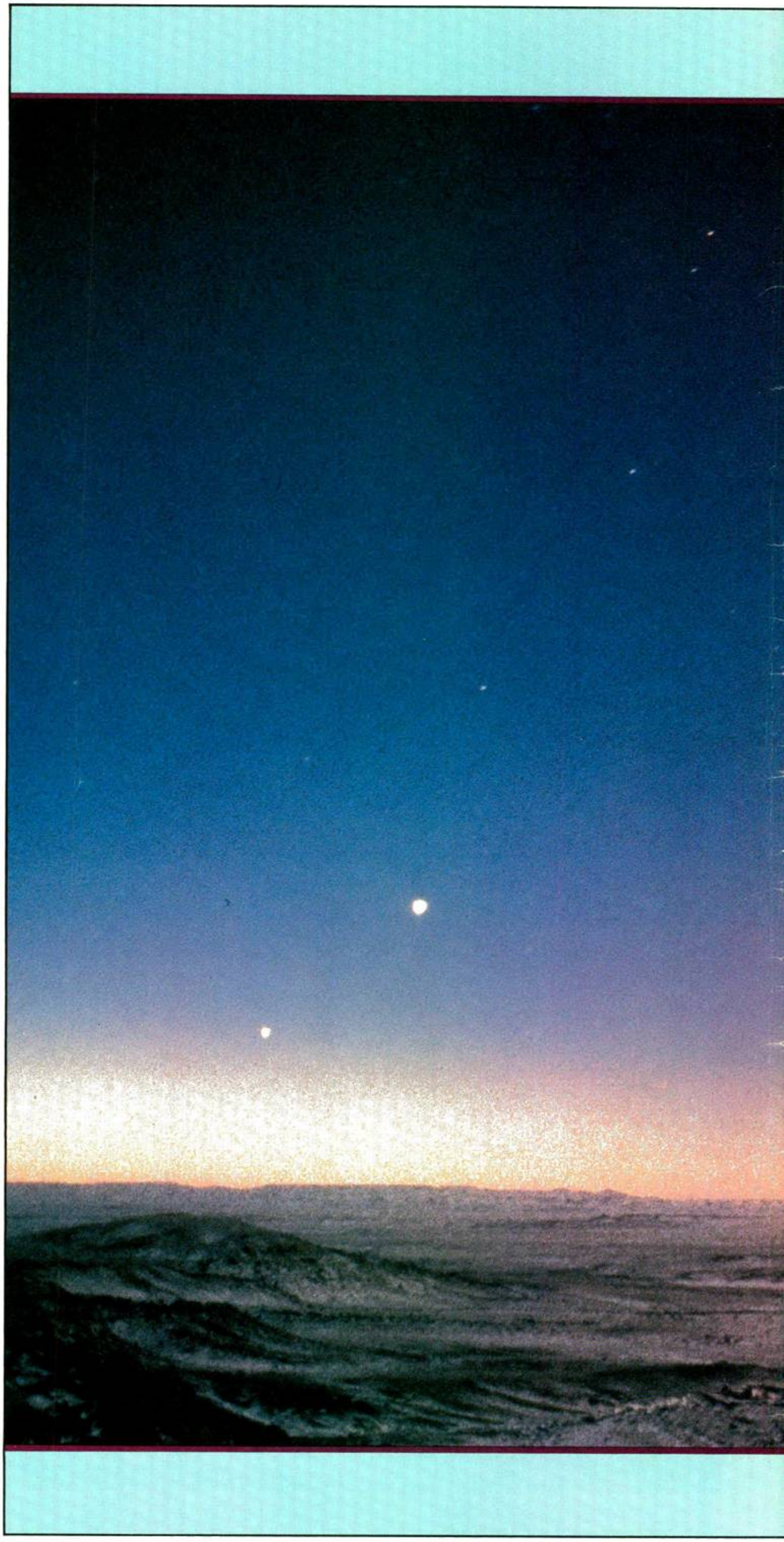
Now about a month past opposition, Mars is at the western end of its retrograde "loop." Though its diameter will shrink by 2.8" of arc — from 17.2" to 14.4" — Mars will still present a very pleasing view in your telescope. Use as high a magnification as the seeing permits, and try observing with a red or a blue filter.



Satellites of Jupiter 8:00 UT

1	12034	16	01234
2	01234	17	10324
3	10	18	32014
4	3240	19	304
5	43012	20	34102
6	43102	21	42031
7	42013	22	42103
8	42103	23	40123
9	40123	24	41032
10	4102	25	43201
11	3240	26	43210
12	304	27	43012
13	31024	28	01
14	20134	29	21043
15	21034	30	02134

Jupiter = 0, Io = 1, Europa = Ganymede =3, Callisto =4
(South is at top, matching the view in a telescope)



Our "Best Astro-Photo" winner is Dewey Vanderhoff's photo of the planets in the morning sky on January 20, 1984. He used a 24mm f/2.8 lens, 400-speed film, and a 16-second exposure.

A red filter (use one of Kodak's gelatin photo-filters) will help you discern the dark markings on Mars by increasing contrast. A blue filter has the opposite effect: it obscures surface markings, but can bring out clouds in the atmosphere.

Asteroids

1 Ceres (magnitude 8.8) is moving slowly northeastward through the tail of Cetus. It lies about 10° north of the variable star Mira. Its positions:

9th: 2h 11m 41s, 4° 56.0′
19th: 2h 24m 45s, 5° 58.8′

Ceres rises around 4 a.m. local daylight time on June 15th.

2 Pallas (10.1) lies in south-central Pegasus, about 5° south of the star Markab (α Peg). Its positions:

9th: 23h 04m 58s, 9° 32.1′
19th: 23h 09m 34s, 9° 50.9′

Pallas rises about midnight local daylight time in the middle of the month.

3 Juno (10.0) is heading eastward through southern Gemini. In conjunction with the Sun on August 7th, it is now too close to the Sun to be seen.

4 Vesta (8.4) is also in Gemini, but northeast of Juno; it, too, is out of view this month, and will reach conjunction on August 10th.

For convenience in plotting their positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

At opposition on June 29th, Jupiter is retrograding about 3° north of the "teapot" of Sagittarius. This month the planet will have an equatorial diameter of 46″ — wider by several seconds than Saturn's rings and a good target for telescopic viewing.

Like Mars, Jupiter is another planet that can benefit from observations using a filter. Try a red or blue one and note how the belts change their appearances. Green and orange filters will also provide interestingly different views.

Saturn

Located in western Libra, Saturn is a promient object in this zodiacal constellation and one of the brighter planets in the evening sky. Physically smaller than Jupiter and twice as far away, Saturn's equatorial diameter measures only about 18″. The rings, however, extend about 41″.

Currently, the northern side of the rings is tipped 19° to our line of sight. Over the next six months, this tilt will imperceptibly increase until it reaches 23° by the end of the year.

Uranus and Neptune

Both planets come to opposition this month — Uranus on June 1st, Neptune on June 21st. See the special Gazer's Gazette starting on page 52 for full observing details.

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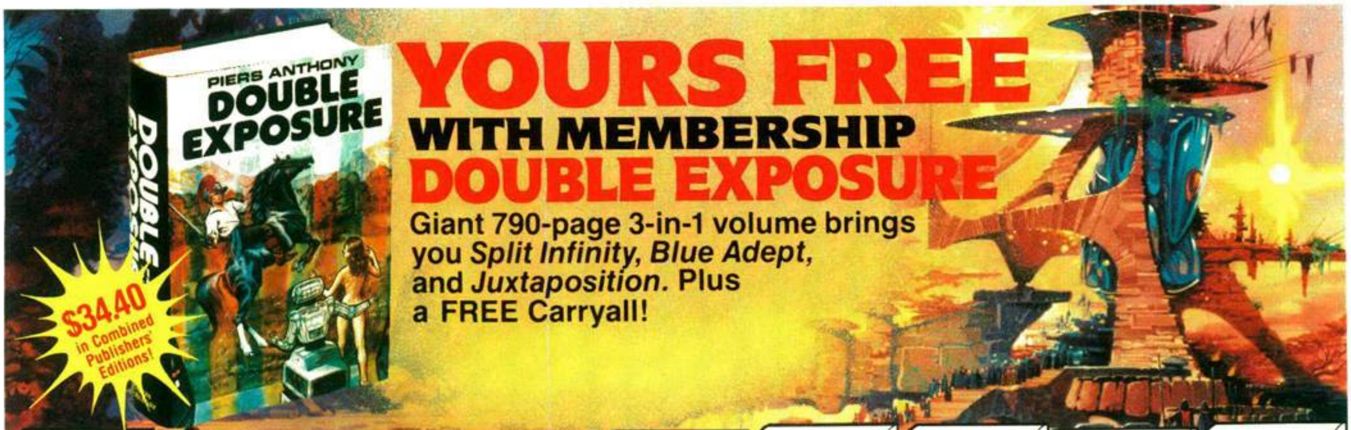
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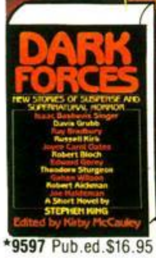
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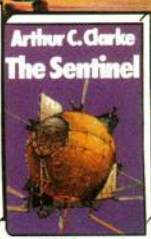
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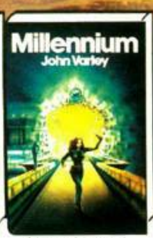
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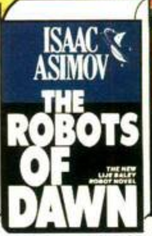
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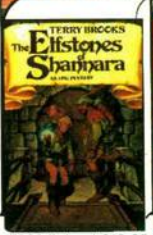
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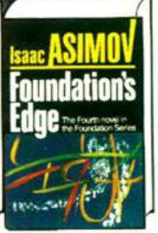
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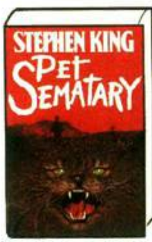
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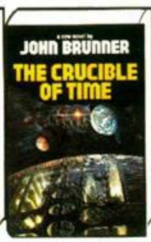
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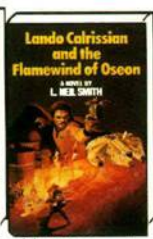
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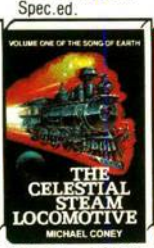
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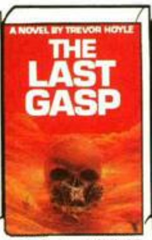
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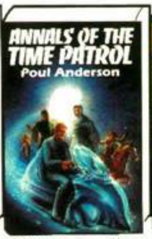
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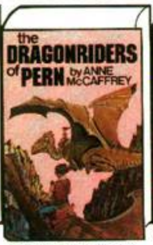
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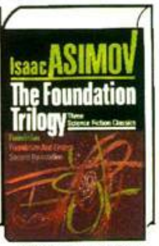
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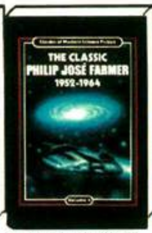
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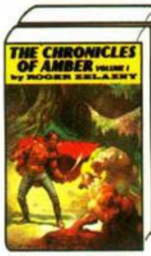
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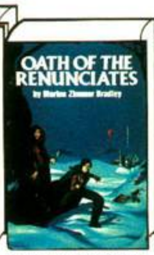
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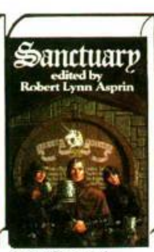
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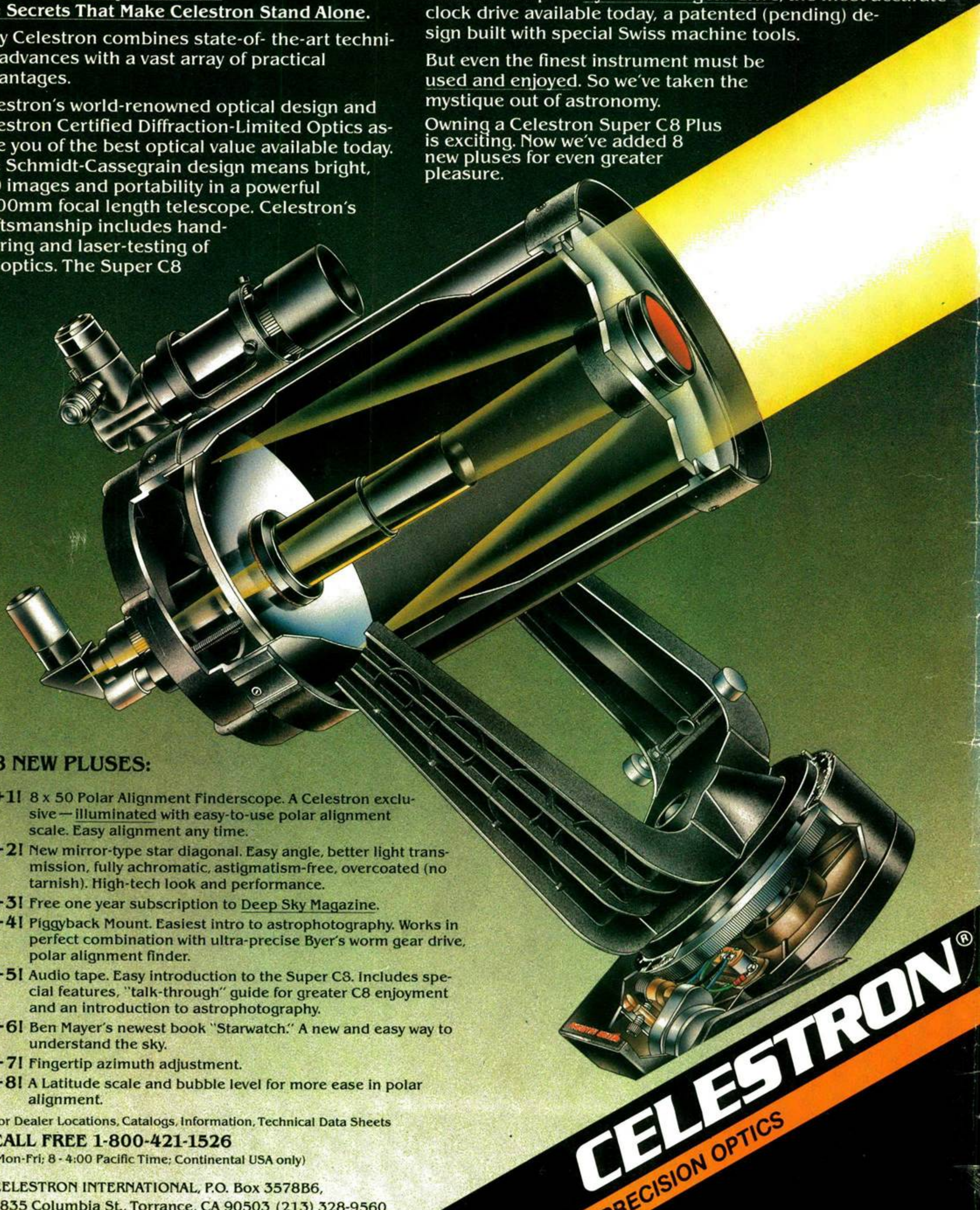

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